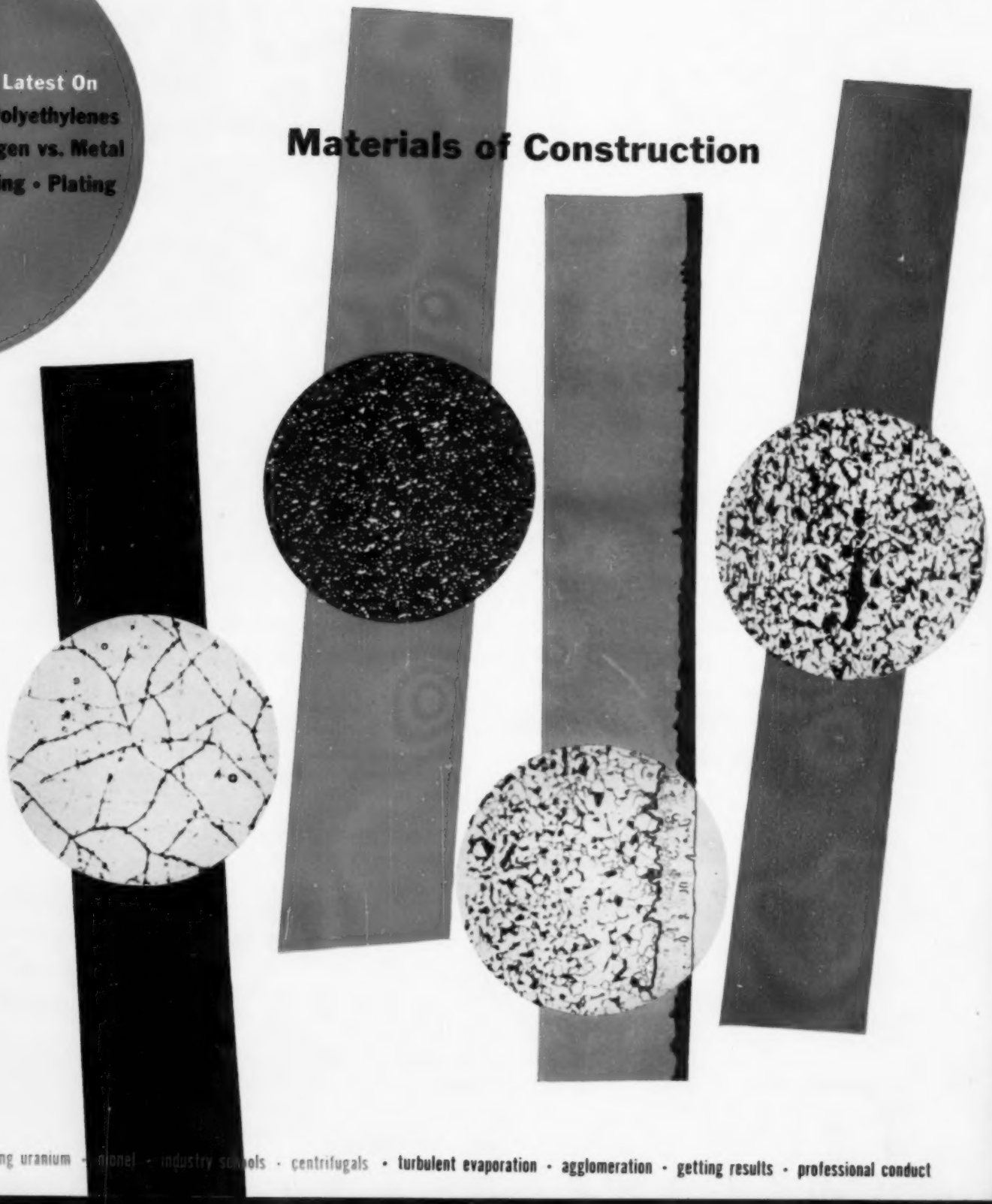
# Chemical Engineering Progress

JUNE 1955

The Latest On
The Polyethylenes
Hydrogen vs. Metal
Cladding • Plating

## Materials of Construction



making uranium · monel · industry schools · centrifugals · turbulent evaporation · agglomeration · getting results · professional conduct

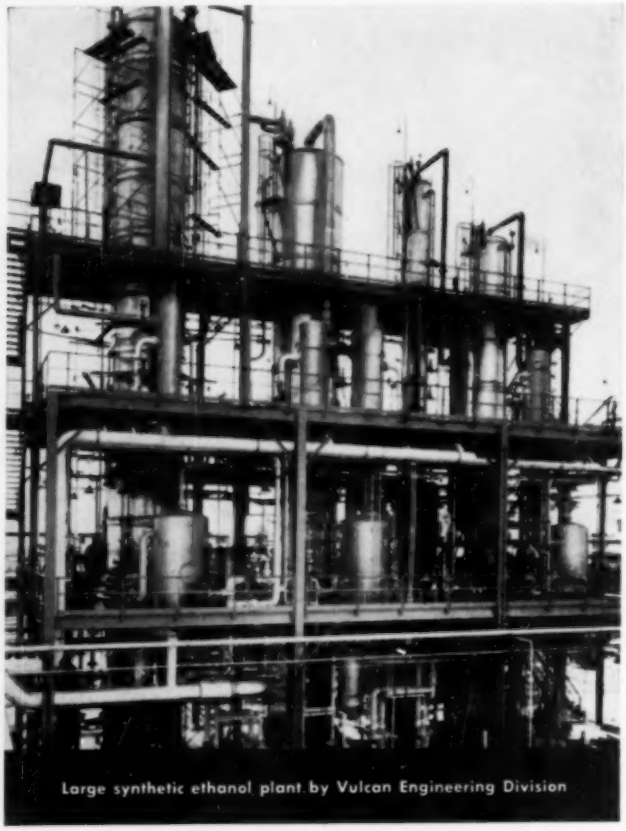
*process know-how for* LOWER ALIPHATIC

# ALCOHOLS

$CH_3OH$
$C_2H_5OH$
$iC_3H_7OH$
$nC_4H_9OH$

**FERMENTATION • SYNTHESIS**
**PURIFICATION**
**DEHYDRATION • RECOVERY**

Vulcan's accumulated experience with lower aliphatic alcohols goes back over 50 years — covers hundreds of installations throughout this country and abroad — establishes Vulcan as the leading designer and constructor of plants and units for production and recovery of alcohols.



Large synthetic ethanol plant by Vulcan Engineering Division

- ★ Production of METHANOL by the Vulcan-Inventa Synthesis Process.
- ★ Production of ETHANOL by fermentation or by synthesis from ethylene.
- ★ Production of ISOPROPANOL by synthesis from propylene.
- ★ Production of N-BUTANOL by fermentation.
- ★ Dehydration by Vulcan's Pressure Process — applicable to the water-miscible alcohols which form constant-boiling mixtures with water.
- ★ Recovery and Purification of methanol, ethanol, normal propanol, isopropanol, normal butanol, secondary butanol, tertiary butanol, isobutanol and several of the amyl alcohols.

*Vulcan's experience will provide the answers for many of YOUR problems in the production or recovery of the lower aliphatic alcohols. Your inquiry is invited.*

## VULCAN ENGINEERING DIVISION

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DIVISIONS OF THE VULCAN COPPER & SUPPLY CO.:

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# Chemical Engineering Progress

JUNE, 1955 • Volume 51, No. 6



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**this month's cover**

**Strips of metal have superimposed their corresponding structural photomicrographs—symbolizing some of the chemical engineer's weapons against corrosion.**

*—cover by Milton Wynne Associates.*


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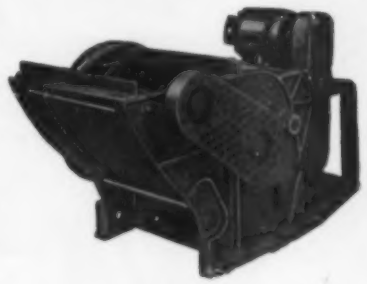
**For a brief description of each article . . . see "What's In This Issue"—page 33**



. . . . . Don't waste production time!



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## . . . and so is the noise

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No. 91500, same as No. 91505, but without motor or base

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Also available with motors for other voltage requirements or with explosion-proof motors. Prices on request.

Here's a vacuum pump that is so carefully designed . . . so expertly machined . . . so perfectly balanced . . . that vibration has been reduced to an absolute minimum. Result . . . smooth, quiet operation. You can hardly hear it as it runs. In fact, its noise level is lower than that of any similar pump.

The new Cenco Hyvac-7 has more pumping capacity per cubic foot of space occupied than any other vacuum pump now available. It produces a free air displacement of 70 liters per minute and a guaranteed ultimate vacuum of 0.1 micron. This pumping speed in the low micron range is exceptionally high. The ratio of pumping speed at 1 micron to that at atmospheric pressure is 49%. And it pumps from atmospheric to ultimate pressure in less than five minutes.

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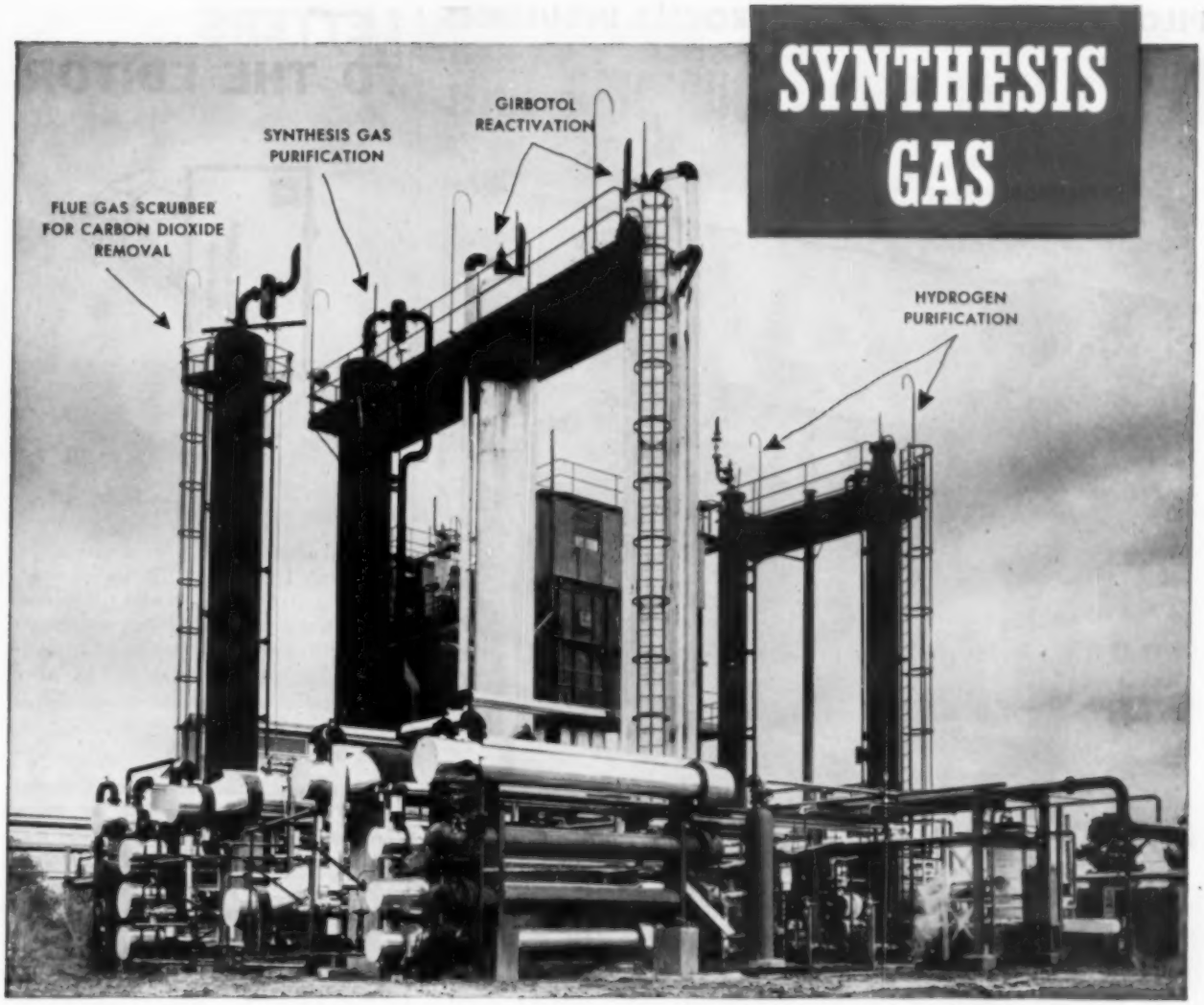
PILOT PLANTS . . . LABS . . . PROCESS INDUSTRIES | LETTERS

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DIVISION OF EASTMAN KODAK COMPANY

TEXAS EASTMAN'S synthesis gas plant at Longview, Texas, produces a mixture of hydrogen and carbon monoxide. In addition, at this installation a separate section of the plant was built to supply high-purity hydrogen.

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| Plastics Materials Plants | Fertilizer Plants |

Catalysts and Activated Carbon

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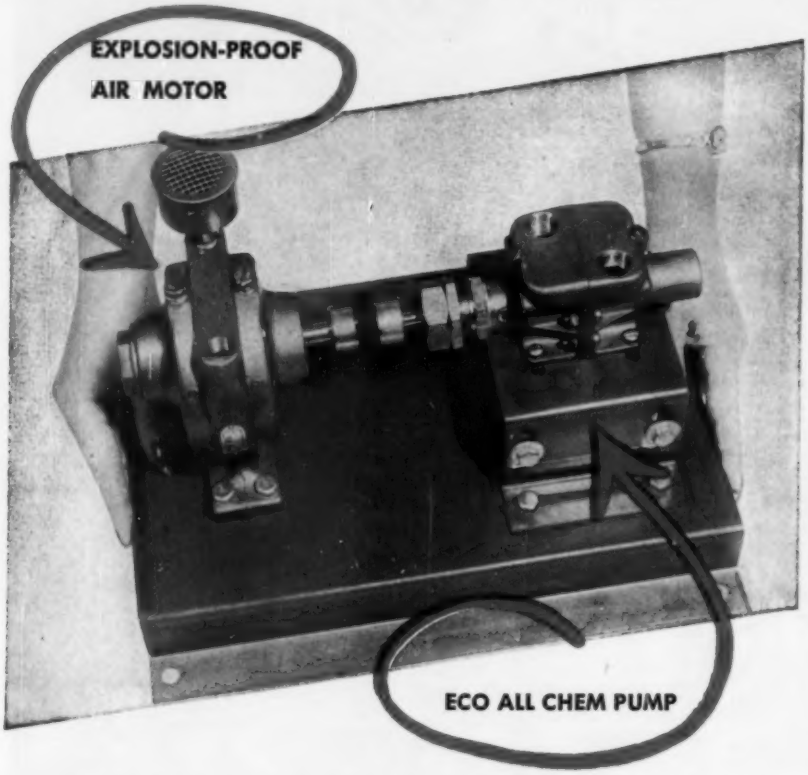
PILOT PLANTS . . . LABS . . . PROCESS INDUSTRIES

here's your safest pumping unit




The leaders in small pump design, ECO ENGINEERING now offers a new, portable explosion-proof variable speed pumping unit. This compact unit combines the time-tested ECO All Chem Pump with a manually controlled variable speed air motor.
It's the safest combination for handling hazardous or corrosive fluids and was designed for labs, pilot plants, chemical process plants, pharmaceutical and nuclear installations.
The ECO All Chem Pump is self-priming with non-volatile fluids and is readily available in a variety of construction materials suitable for dependable, low-cost pumping of non-abrasive fluids.
ECO can make immediate shipment of the complete unit in capacities from 0 to 10 GPM and pressure to 100 PSIG.
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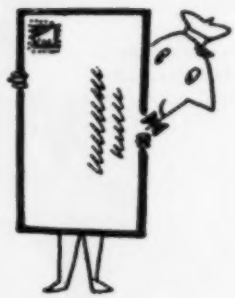
# LETTERS TO THE EDITOR



**C.E.P. Rings the Bell.**

. . . again belated, I want to mention how much I feel that CEP has improved over the last several months. The new covers and layout are terrific—much more inviting to serious readership.

DOUGLAS M. CONSIDINE
Indianapolis, Ind.

**Costs—Perennially Interesting**

Your presentation (Costs of Chemical Plant Auxiliaries) interested me extraordinarily and I am most convinced that all my colleagues will share my interest.

HORST MEISSNER
Leverkusen-Bayerwerk

The writer of this letter refers to an article "Estimating Costs of Plant Auxiliaries," by H. C. Bauman of the Chemical Construction Corporation, New York, which was run in the January, 1955, issue of C.E.P.

—EDITOR

**Wants Titles of Articles in Literature Cited**

I recommend that your form for literature citations be altered by including titles of articles. This will make the bibliography more worth while to those who use it.

SIDNEY GROSS
Seattle, Washington

**A Make-Up Plan Offered**

I would like to suggest to you that in arranging technical articles in CEP that you follow a rule that two different articles will appear neither on the same page nor on opposite sides of the same page.

I am sure there are many persons besides myself who find articles in the magazine of sufficient interest to warrant clipping and filing. In those cases in which two different articles appear on the same sheet,

(*Continued on page* 12)

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*infrared*
*Spectrophotometer*

*for research*
*and*
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Let us send you complete information and cost data on this research – quality control instrument.

***Write for data file 65-35.***

*Beckman Division*

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**NEW HIGH SUSTAINED ACCURACY . . .** even under extreme operating and ambient conditions

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# d/p Cell Flow Transmitter...

**NEW** POSITIVE OVERRANGE PROTECTION . . . up to full 1500 lbs. cell rating

# 6 Major Achievements!

**NEW** FULLY ADJUSTABLE RANGE . . . from 0-50" to 0-250" $H_2O$ differential

**NEW** AUTOMATIC INTERNAL DAMPING . . . fast, stable measurement

**NEW** SIMPLICITY . . . lowest cost installation

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*Reg. U. S. Pat. Off.

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*first in flow measurement*

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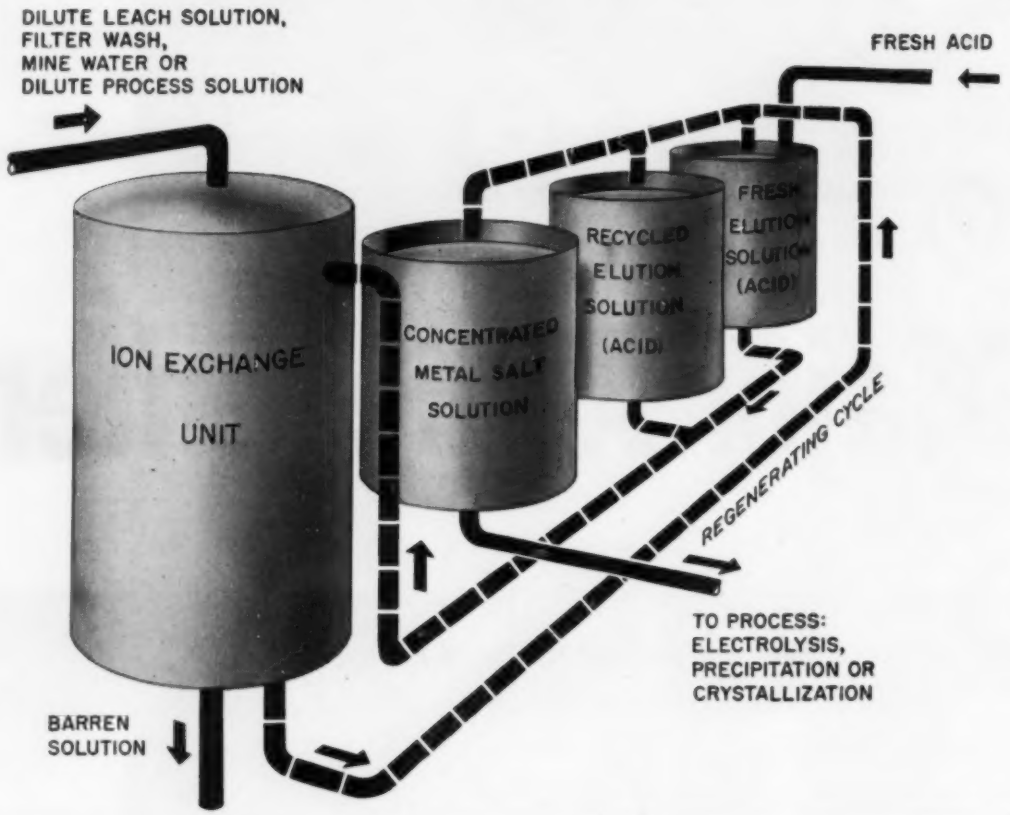
Lapp Valves — Solid Porcelain

## METAL CONCENTRATION BY ION EXCHANGE

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# Ion Exchange gives Better Yields

• Ion exchange increases yields, simplifies flow sheets and cuts labor, supervision and chemical costs when used with other hydrometallurgical processes such as Leaching, Clarification, Filtration, Purification, Precipitation and Electrolysis.

The simplified flow diagram shown above illustrates the main principles of ion exchange in concentrating metals from leach liquors, filter washes, other dilute process solutions or mine waters:

As the feed solution or mine water passes through the ion exchange unit, the metal values are concentrated on the ion exchange resin, generally in preference to other ions present, leaving the solution or mine water metal-free. When the metal-attracting property of the resin is exhausted, an appropriate elution solution, for example an acid, is passed through the resin to pick up the metal. In most cases, the elution solution also acts as regenerant to restore the metal-attracting capacity of the resin . . . as shown on the diagram. Recycling the elution solution provides high concentrations . . . often several thousand times as concentrated as the original feed solution.

**Ion Exchange methods apply to these metals:**

| Base Metals | Minor Metals | Precious Metals |
|---|---|---|
| Copper | Cobalt | Gold |
| Zinc | Tungsten | Silver |
| Lead | Molybdenum | Platinum |
| Tin | Vanadium | **Rare Earths** |
| Aluminum | **Decorative Metals** | Lanthanide Group |
| | Nickel | Actinide Group |
| | Chromium | Uranium |

*The Permutit Company not only designs and builds complete ion exchange systems, but also manufactures ion exchange resins and zeolites for all industrial applications. For information, write: The Permutit Company, Dept. CEP-6, 330 West 42nd St., New York 36, N. Y.*

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# Lapp Valves are Solid Porcelain

You need to make no compromise with contamination or corrosion from valves in chemical processing. Lapp valves are of *solid* Lapp Porcelain, a material unique as a ceramic for industrial scale chemical service. It alone offers the following combination of characteristics and qualities:

**PURITY** • Lapp Porcelain is a potassium aluminum silicate, made from selected clays, flint and feldspar... has no free iron or other metallic impurity.

**NON-POROUS** • Complete vitrification of all sections, through firing to 2300°F., provides *zero* porosity. No dye penetration of body in 100,000 psi test. No chemical can penetrate in service.

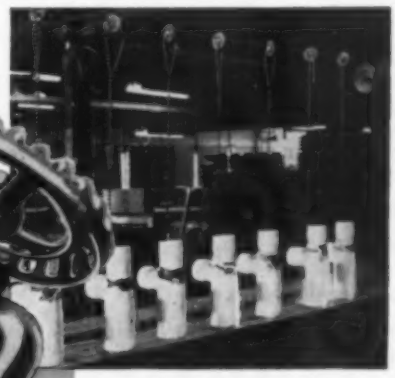
**HIGH MECHANICAL STRENGTH**

Compression strength ..... 100,000 lbs. per sq. in.
Tensile strength ..... 8,000 lbs. per sq. in.
Modulus of rupture ..... 15,000 lbs. per sq. in.

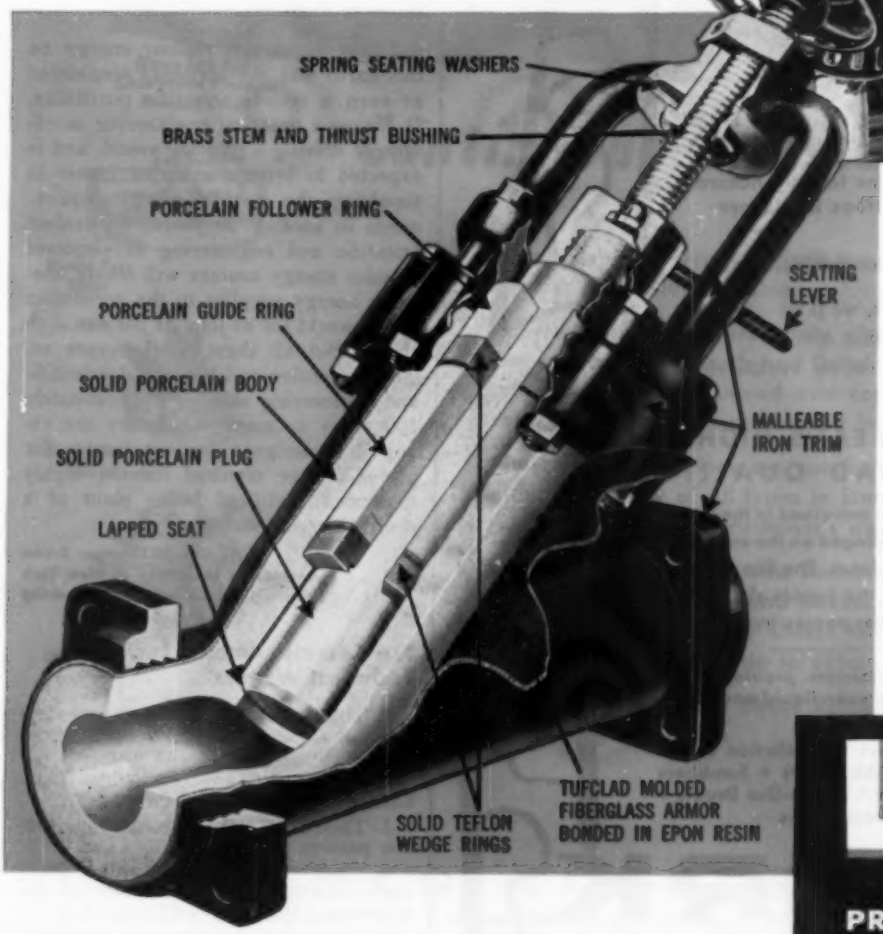
**CHEMICAL RESISTANCE** • Lapp Porcelain is unaffected by any acids except HF. It provides years of trouble-free service, handling hot acids in all concentrations, as well as mixed acids and other troublesome combinations.

**UNIFORM QUALITY** • Lapp Porcelain has been manufactured for 38 years for use in most severe chemical, electrical and mechanical services. Plant facilities include Lapp-patented vacuum processing, deaerating pug mills, two continuous tunnel kilns, and complete chemical, electrical and mechanical test equipment.

*Write for bulletin with complete description, characteristics, and specifications. Lapp Insulator Co., Inc., Process Equipment Division, 461 Wendell St., LeRoy, N. Y.*



*An electrical test is the most searching inspection for physical soundness! Porcelain bodies for Lapp valves above are being flashed over—at 70,000 volts for three minutes. Any physical defect is revealed as an electrical puncture.*

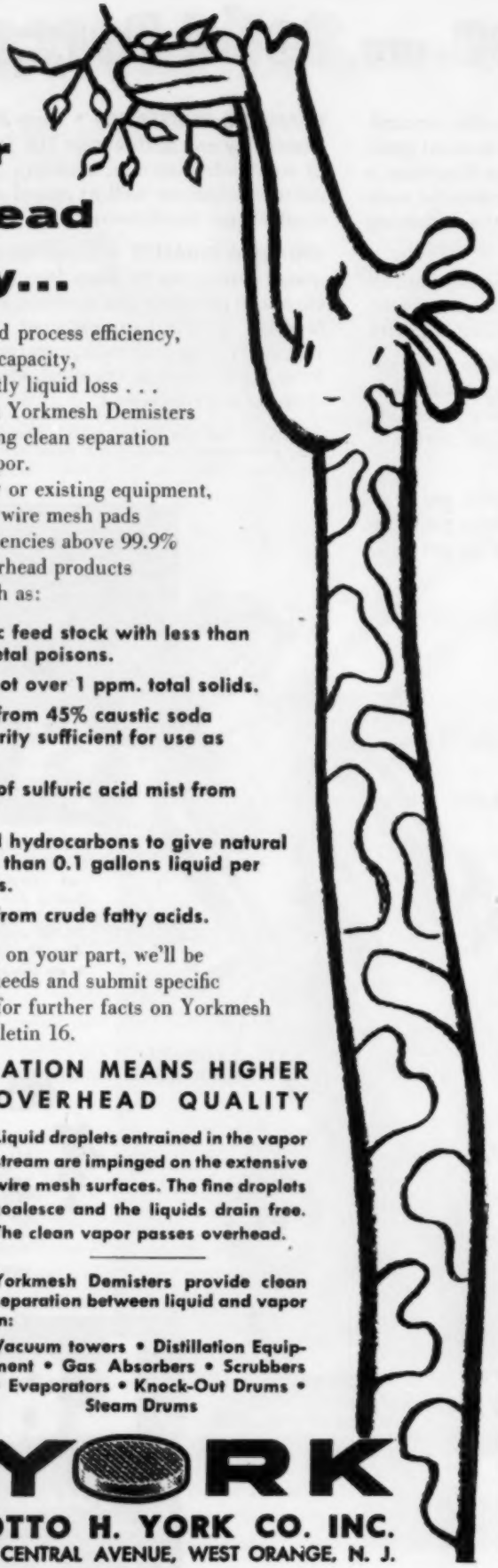


*Y-valves, angle valves, flush valves, safety valves, and plug cocks of Lapp Porcelain have standard bolt-circle flanges for easy connection to all piping and equipment.*

**Lapp**

**PROCESS EQUIPMENT**

Chemical Porcelain Valves • Pipe • Raschig Rings
Pulsafeeder Chemical Proportioning Pumps



# higher overhead quality...

. . . PLUS — improved process efficiency, increased throughput capacity, the elimination of costly liquid loss . . . may be obtained when Yorkmesh Demisters are on the job providing clean separation between liquid and vapor.
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- **Separation of liquid hydrocarbons to give natural gas containing less than 0.1 gallons liquid per million cu. ft. of gas.**
- **Colorless distillate from crude fatty acids.**

Without any obligation on your part, we'll be pleased to study your needs and submit specific recommendations. Or, for further facts on Yorkmesh Demisters write for Bulletin 16.

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**Liquid droplets entrained in the vapor stream are impinged on the extensive wire mesh surfaces. The fine droplets coalesce and the liquids drain free. The clean vapor passes overhead.**

**Yorkmesh Demisters provide clean separation between liquid and vapor in:**

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## LETTERS TO THE EDITOR

*(Continued from page 6)*

and are to be filed separately, it becomes necessary to obtain a photo reproduction of one side. In other magazines, suitable arrangement is often achieved by placing advertisements on odd pages.

As a specific case in point, the last issue of CEP (Vol. 51, No. 1 of January 1955) had an interesting article on dust collection (Filtration of Radioactive Aerosols by Glass Fibers) on page 11-J [This article began on page 6-J and ended on 11-J.] married to an equally interesting article on ammonia plant economics (Economics of Ammonia Manufacture From Several Raw Materials) on the opposite side, page 12-J.

WARREN FUCHS
New York, New York

## NOTED AND QUOTED

### Once-Remote Nuclear Energy—Now a Reality

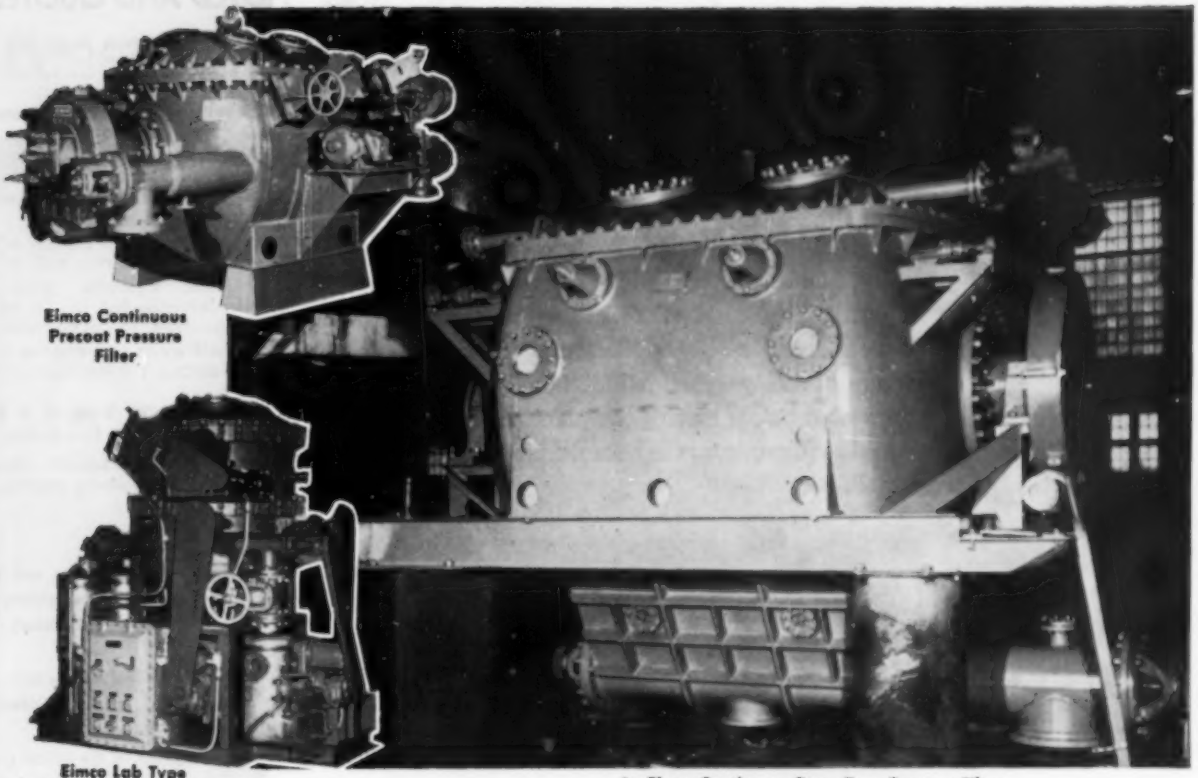
Thirty years ago nuclear energy on this earth was not seriously considered as even a remote scientific possibility. It is now a practical engineering development driving a military vessel, and is expected to become a major factor in supplying the world's energy requirements in another 30 years. Equivalent scientific and engineering development of solar energy sources will insure adequate energy supplies to the population of the world for as long as the sun doth shine. But all these developments require extensive and high-level scientific and engineering ability. Approximately 100 times as many man-hours are required to design a nuclear reactor for power as are required for the highly developed coal-fired boiler plant of a central service station.

**George Granger Brown**
**Centennial Convocation of New York University's College of Engineering**

### Ten Commandments for Technical Writers

1. Thou shalt remember thy readers all the days of thy life; for without readers thy words are as naught.
2. Thou shalt not forsake the time-honored virtue of simplicity.
3. Thou shalt not abuse the third person passive.
4. Thou shalt not dangle thy participles; neither shalt thou misplace thy modifiers.
5. Thou shalt not commit monotony.

*(Continued on page 14)*



Eimco Continuous Precoat Pressure Filter

Eimco Lab Type Continuous Pressure Precoat Drum

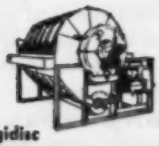
An Eimco Continuous Drum Type Pressure Filter

# Continuous Pressure Filtration

Eimco Pan Filter

Eimco Pressure Roll Filter

Eimco Bi-Carb Filter



Eimco Agidisc Filter

**offers a means of solving difficult process problems which have heretofore been unanswerable.**

**These filters are offered only after the problem has been studied by Eimco's Research and Development Division and each filter station is then designed and constructed to handle each user's problem on an assured result basis.**

**Pilot plant operations are conducted on proportional sized filtration equipment of all types in Eimco's Research and Development Center or in the customer's own plant.**

**Successful production size installations based on findings made by Eimco's Research and Development Division prove the value of starting new flow sheets through this thorough and exhaustive method of testing to obtain all the facts.**

**Let us tell you more about Research in liquids-solids separation through filtration.**

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B-124

# every Chemiseal Expansion Joint is pressure tested at the plant

***(and Flexural Tested, too, for Special Requirements)***

made of du Pont TEFLON

To be sure that Chemiseal Expansion Joints and Flexible Couplings not only protect the costly chemical piping which they connect—but will also meet the service pressure requirements of every installation with a wide margin of safety—each is individually pressure tested before leaving the plant. And for special requirements, they are flexural tested as well.

Use these Safe Seals that absorb shock, vibrations, thermal expansion and contraction—Correct misalignment of piping—Eliminate gaskets, adaptors, and slip joints—Connect unlike piping ends and nozzles—Are as chemically impervious as the piping they connect because they are made of duPont TEFLON.

Ask your Industrial Distributor or write for Bulletin FC-952.

**UNITED STATES GASKET CO.**
Camden 1, New Jersey

USG

**FABRICATORS OF FLUOROCARBONS AND OTHER PLASTICS**

Representatives in principal cities throughout the world


## NOTED AND QUOTED

(*Continued from page* 12)

6. Thou shalt not cloud thy message with a miasma of technical jargon.

7. Thou shalt not hide the fruits of thy research beneath excess verbiage; neither shalt thou obscure thy conclusions with vague generalities.

8. Thou shalt not resent helpful advice from thy editors, reviewers, and critics.

9. Thou shalt consider also the views of the layman, for his is an insight often unknown to technocrats.

10. Thou shalt write and rewrite without tiring, for such is the key to improvement.

**Elmer W. Shaw, U. S. Forest Service, Fort Collins, Col.**

**Read at Conference on Scientific Editorial Problems at the A.A.A.S. Berkeley meeting.**

∫

**1. Thou shalt keep remarks concise and clear with kindly consideration for thy neighbors' lack of experience. (The editors will smooth your English).**

**2. Thou shalt not mess up thy article with crowded type, dim ink, late illustrations, or hand-written hieroglyphics.**

**3. Thou shalt return proof to the editor pronto, remembering a dozen others must work on it before you get a magazine. (The printer has a deadline).**

**Contribution from the printshop**

### 15 Words

Five most important words: "I am proud of you."

Four most important words: "What is your opinion?"

Three most important words: "If you please."

Two most important words: "Thank you."

Least important word: "I."

**The Clarkson Letter**
**Clarkson College of Technology**

### Industry-Within-An-Industry

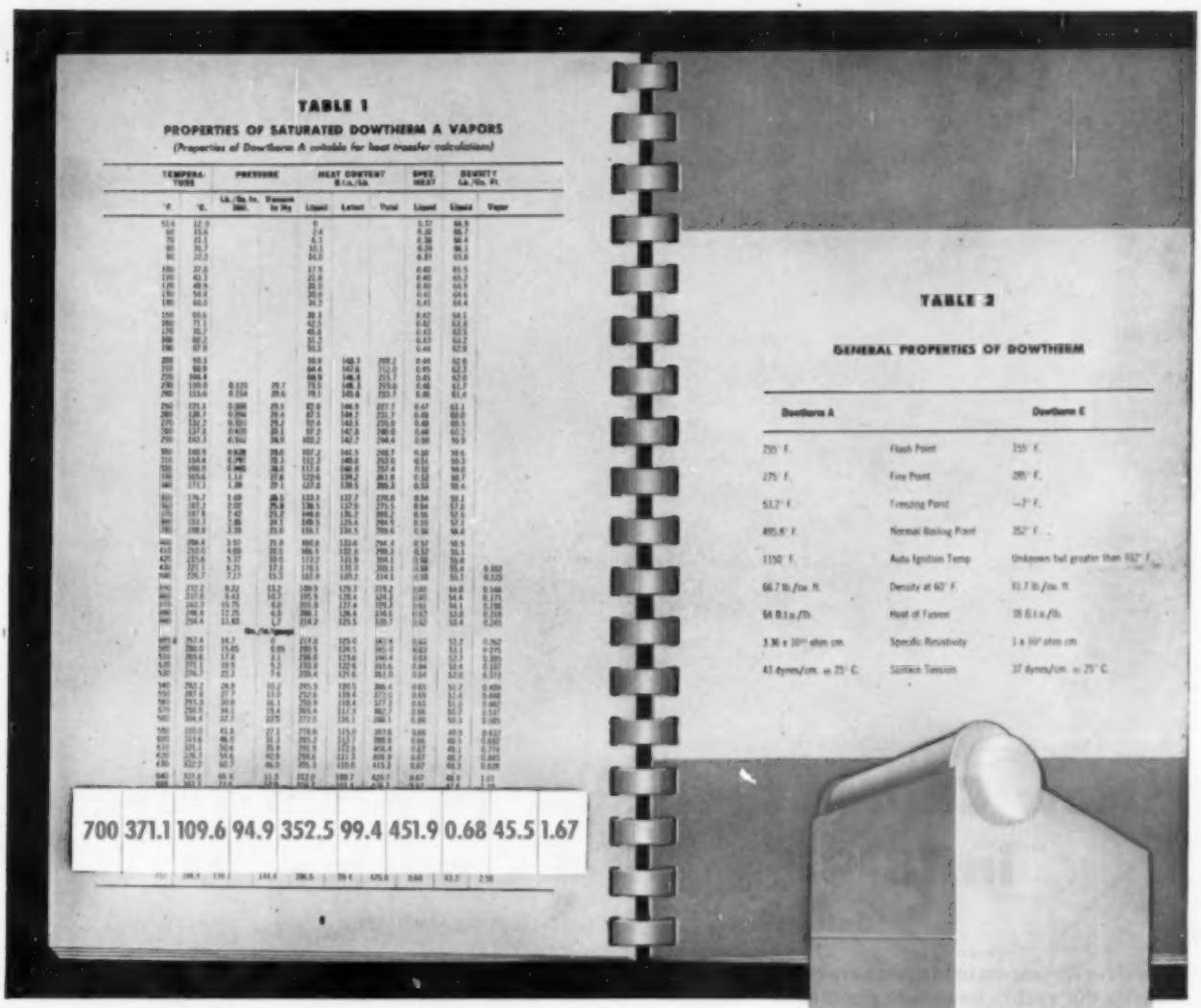
Petrochemicals, chemicals derived from natural gas and petroleum, accounted for more than 25 per cent of this country's total chemical production during 1954 and indications are that by 1965 they will account for more than 50 per cent. . . .

Butylenes, derived from a number of processes including catalytic cracking and butane dehydrogenation, constitute [an] excellent source of petrochemicals. Products into which they may be converted: butadiene, for synthetic rubber

(*Continued on page* 24)

DOW

# Pressure Problems In Process Heat?




## DOWTHERM A

**—pressure only 95 psig at 700°F.**

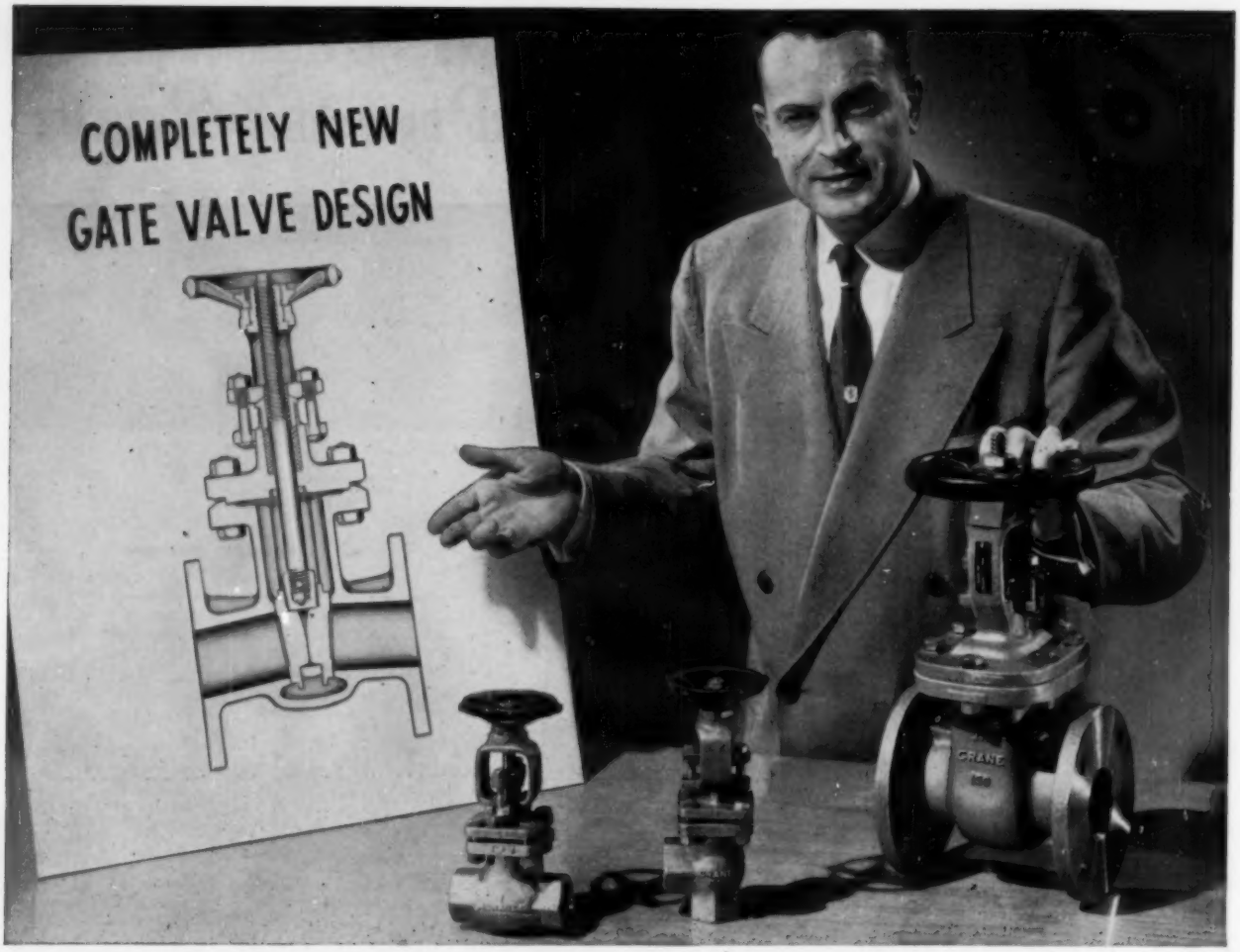
Taking a page from the Dowtherm Handbook—high temperatures *do not* create high pressures when you use the modern heat transfer medium, Dowtherm®. The savings are obvious in less expensive, thinner walled equipment that occupies far less space.

When Dowtherm is used, heat can be controlled with *fraction-of-a-degree accuracy* by simple pressure regulation. Dowtherm provides low-pressure, high-temperature heat, extending the advantages of vapor-phase heating to much higher temperatures. The extraordinary thermal stability of Dowtherm makes it a natural for those applications demanding liquid-phase heating.

Your foresight in investigating Dowtherm may provide your company's competitive edge of the future. You'll find all the facts in the "*Dowtherm Handbook*", a valuable technical guide of process heat information. A request on your letterhead will bring it to you promptly. THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. DO 726A-1.

*you can depend on DOW CHEMICALS*

DOW




# New CRANE Corrosion-resistant valves in 18-8 SMo and Craneloy 20

### Gate, Globe, Angle and Check Patterns

Few valves for process industries have ever received the quality treatment given this new Crane line—at prices you'll find O.K.

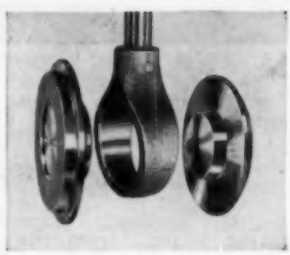
Note, for instance, the unique yet simple split-wedge disc construction in the gate valves. Those dual identical discs are free to rotate in their holder—the most effective design for resisting galling. The trunnion shape at the back of each disc assures even distribution of closing forces. You couldn't buckle them if you tried.

The globe and angle valves give equally outstanding control of corrosive fluids. A new type disc-stem connection, with minimum clearances, practically eliminates vibration. By placing seating load closer to seats, it provides easier, more accurate closure.

Check valves feature compact, thoroughly proved, non-slamming design.

Throughout, these valves are built for better service in your choice of Crane 18-8 SMo Stainless Steel or Craneloy 20. Both lines come with screwed or flanged ends.

**ASK FOR THIS CATALOG**—Full information including service suggestions given in circular AD-2080—available from your Crane Representative or by mail. Crane Co., General Offices: Chicago 5, Ill. Branches and Wholesalers everywhere.



New split-wedge disc in gate valves combines the benefits of free rotation with uniform seat load pressure.

## CRANE CO.

VALVES · FITTINGS · PIPE
KITCHENS · PLUMBING · HEATING

CRANE'S FIRST CENTURY...1855-1955

# SULPHUR GOES ATOMIC

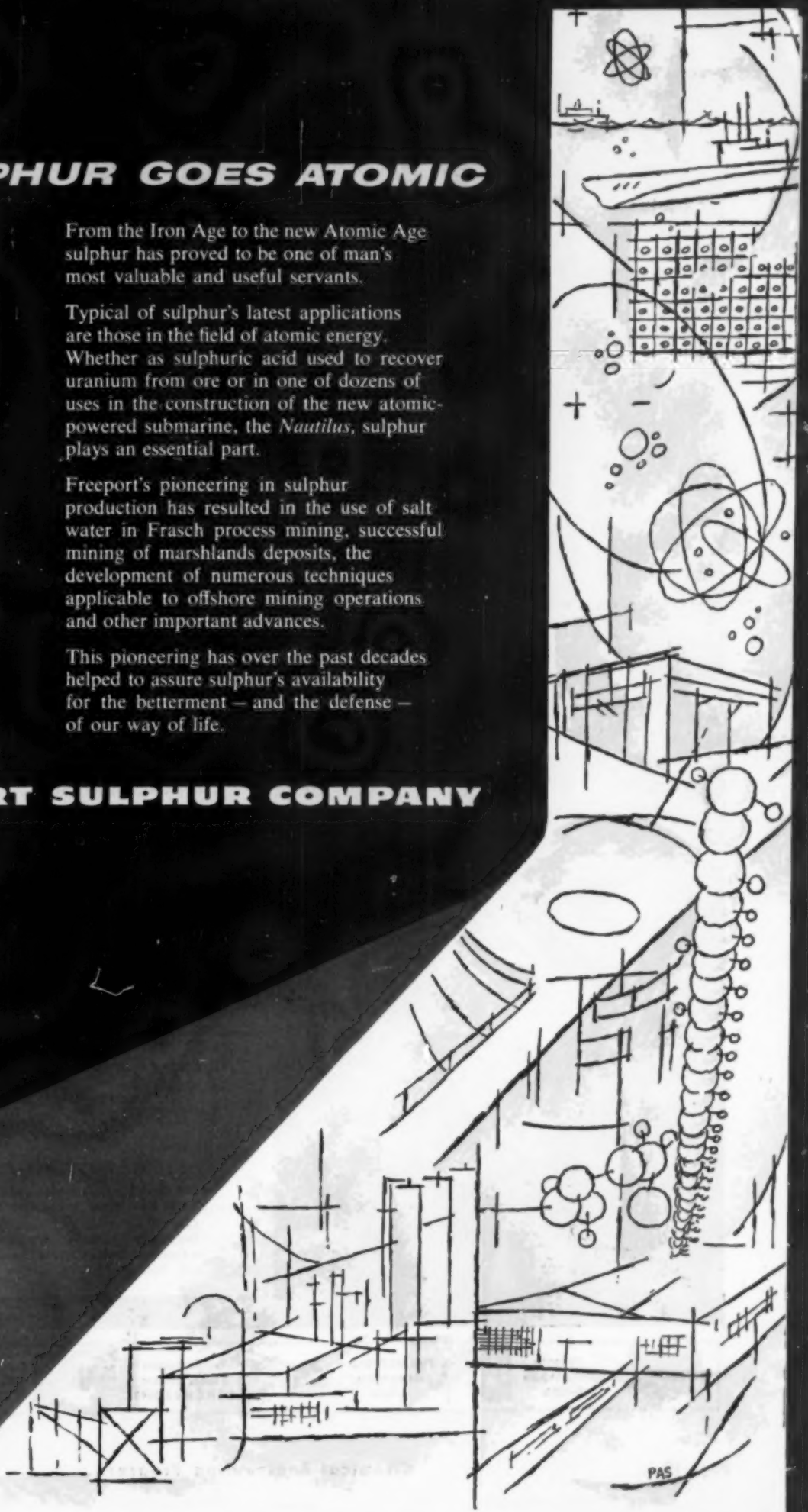
From the Iron Age to the new Atomic Age sulphur has proved to be one of man's most valuable and useful servants.

Typical of sulphur's latest applications are those in the field of atomic energy. Whether as sulphuric acid used to recover uranium from ore or in one of dozens of uses in the construction of the new atomic-powered submarine, the *Nautilus*, sulphur plays an essential part.

Freeport's pioneering in sulphur production has resulted in the use of salt water in Frasch process mining, successful mining of marshlands deposits, the development of numerous techniques applicable to offshore mining operations and other important advances.

This pioneering has over the past decades helped to assure sulphur's availability for the betterment – and the defense – of our way of life.

**FREEPORT SULPHUR COMPANY**



We've found that "KARBATE" equipment cuts costs wherever corrosion is a factor!

# WHY SHOULD YOU USE KARBATE BRAND IMPERVIOUS GRAPHITE PROCESS EQUIPMENT?

**ANSWER: Because *only* "Karbate" products combine:**

- Corrosion resistance
- Immunity to thermal shock
- Freedom from metallic contamination
- High thermal conductivity
- Low first cost *and* low maintenance
- Workability — readily fabricated and serviced in the field
- Sturdy, durable constructions
- Standard stock units
- Complete technical service

**Manufactured Only By National Carbon Company**

"Karbate" impervious graphite is a "must" in many highly corrosive services. But these applications only begin to measure the possibility of savings offered by "Karbate" products in a wide range of process locations. Wherever corrosion, contamination or thermal shock must be eliminated, "Karbate" products save time and money all the way down the process line.

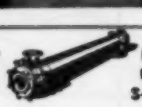
**WRITE FOR LITERATURE!**

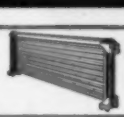
*The term "Karbate" is a registered trade-mark of Union Carbide and Carbon Corporation*

**NATIONAL CARBON COMPANY**
**A Division of Union Carbide and Carbon Corporation**
***30 East 42nd Street, New York 17, N. Y.***
*Sales Offices:* Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco
IN CANADA: Union Carbide Canada Limited, Toronto

Pumps — Catalog Section S-7250

Pipe and Fittings — Catalog Section S-7000


Heat Exchangers — Catalog Sections S-6740 and S-6840


Cascade Coolers — Catalog Section S-6820

HCl Absorbers — Catalog Section S-7480

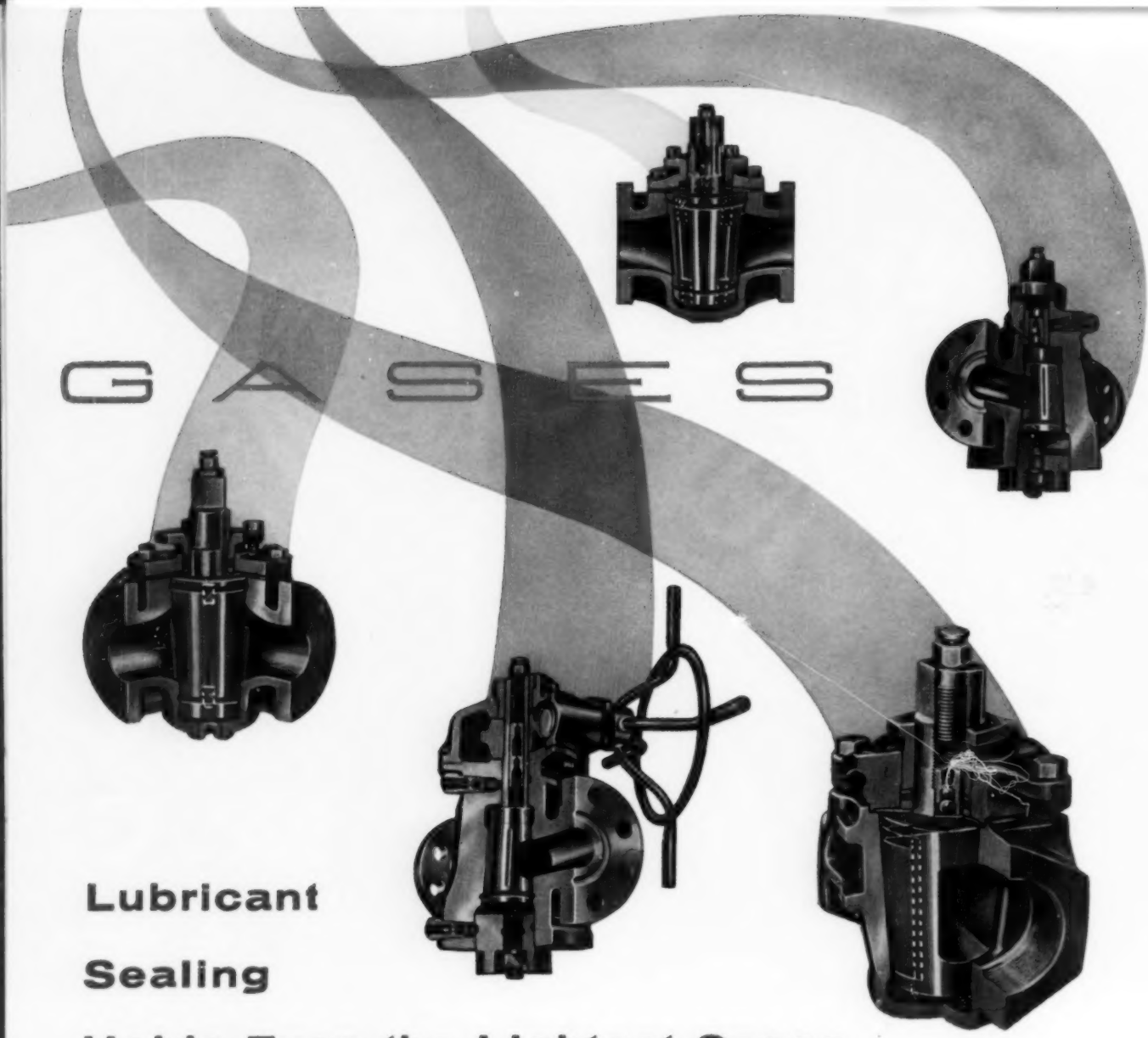
# Dependable

Rockwell-Nordstrom, *the* quality valve, is the most dependable valve you can use because it's *pressure lubricated.* Whether it is operated once a year or once every hour, the unique pressure lubrication system is always at work eliminating metal-to-metal friction, providing a leak-proof seal, and cushioning the plug for easy operation.

Rockwell-Nordstrom valves and plug valve lubricants are an investment you can always depend on for dividends in trouble-free service. Why not follow the leaders who have used Rockwell-Nordstrom valves for forty years? Rockwell Manufacturing Company, Pittsburgh 8, Pa.

ROCKWELL-Nordstrom VALVES

LUBRICANT SEALED FOR POSITIVE SHUT-OFF




## Lubricant Sealing Holds Even the Lightest Gases

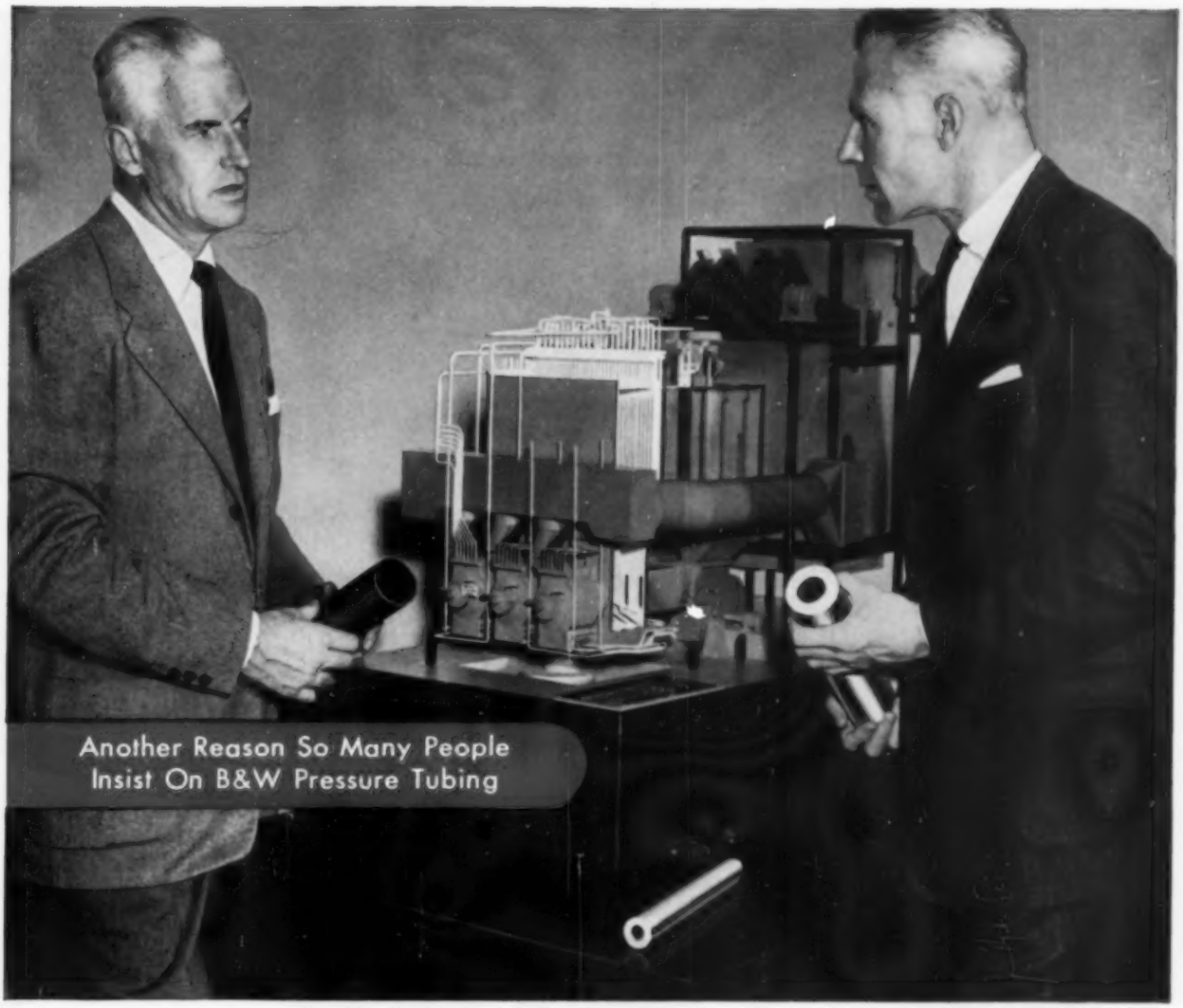
Rockwell-Nordstrom valves are the most efficient valves for any gas service because they're *lubricant sealed.* The unique Sealdport* grooves in the plug and body carry pressurized lubricant which forms a truly leak proof seal for the lightest hydrocarbons. Ordinary valves depend solely upon risky metal-to-metal closure where one tiny scratch means a leak.

Whatever your gas control problems, there is the perfect combination of Rockwell-Nordstrom valve and lubricant to do the job more dependably and economically than any other valve you've ever used. Write on your letterhead today for full details. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

*a registered trademark of Rockwell Manufacturing Company

# ROCKWELL-Nordstrom VALVES

LUBRICANT SEALED FOR POSITIVE SHUT-OFF




# UNDER PRESSURE? TRY 4500 PSI AT 1150 F

There's a new concept in big boiler design: The Universal Pressure Steam Generator. It operates either below the critical—3206 psi—or smashes through the pressure barrier. A unit now being built has a design pressure of 5500 psi, delivers steam at 4500 psi and 1150 F. It's a "once-through" unit; put water in one end of a tube and steam comes out the other, without using a steam drum.

When B&W engineers designed this new boiler they turned to their own metallurgical and tubular products experience with alloys for pressure and temperature service to devise the tubing complex that is the heart of the unit. The chart shows the variety of analyses in sizes from 1-inch O.D. to 2½-inch O.D. and wall thicknesses from 0.10-inch to 0.55-inch.

Carbon Steel • Carbon Moly
Croloy ½ • Croloy 1
Croloy 1¼ • Croloy 2¼
Croloy 3M • Croloy 9M
Croloy 18-8

The best way to avoid operating under *personal* pressure on any job is to call for B&W Pressure Tubing. There's a grade, size, length and wall for virtually every pressure, temperature and corrosion resistance requirement. *Write for Technical Bulletin 6.* CEP.

B&W
TUBULAR PRODUCTS DIVISION

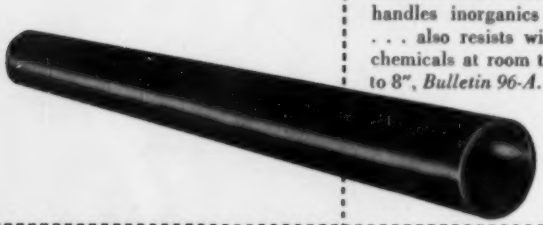
**THE BABCOCK & WILCOX COMPANY**
***TUBULAR PRODUCTS DIVISION***
Beaver Falls, Pa. and Milwaukee, Wis.: Seamless Tubing, Welded Stainless Steel Tubing
Alliance, Ohio: Welded Carbon Steel Tubing
Milwaukee, Wis: Seamless Welding Fittings

TA-5028(P)

**FOR HOT CORROSIVES:**

***ACE TEMPRON***

Heat-resistant nitrile hard rubber pipe handles inorganics at 250-275 deg. F. . . . also resists wide range of organic chemicals at room temperature. Sizes 1" to 8", *Bulletin 96-A.*



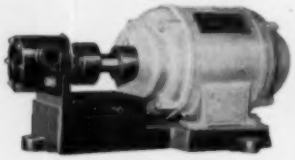
**ACE** chemical equipment

"more resistant to more corrosives"

From this "super-market" of corrosion-resistant equipment . . . backed by more than a century of engineering experience . . . you can select with confidence.

**MIGHTY MIDGET**

***for pumping acids***



Jabsco neoprene-impeller pump made of ACE hard rubber outlasts, out-pumps anything in its pressure, size and price class. Capacity from 15 gpm. at 22 ft. head to 5 gpm. at 72 ft. head. *Bulletin 97-A.*

**SENSITIVE, BUT KEEPS YOUR HEAD**

***ACE Darling Swing Check Valve . . .***

lined with ACE hard rubber for the best in corrosion resistance. Large, straight-through flow areas. Sensitive to slight pressure differential. Non-slamming. Sizes 2" to 24". *Bulletin CE-52.*

**TOUGH ACE-ITE PLASTIC PIPE**

General-purpose moderately priced rubber-plastic pipe handles most common chemicals to 170 deg. F. . . . except few strong acids and organic solvents. Tough, odorless, tasteless. Rigid pipe ½" to 6". *Bulletin 80.*

**VALVES**

***for all-plastic piping systems***

Trouble-free plastic diaphragm valves . . . choice of general-purpose rubber-plastic blend, Ace Parian (polyethylene) or Ace Saran. Handles most corrosive chemicals and food ingredients. Sizes ½" to 2", 50 psi. at 77° F. *Bulletins 80 and 351.*

**1001 USES *for ACE-FLEX Tubing***

Excellent chemical-resistant, all-purpose flexible plastic tubing. Sparkling clear, easy to clean, odorless, non-toxic, can be steam-sterilized. ⅛" to 1" ID. *Bul. 66.*

**ACE-HIDE ACID PAIL**

***Practically indestructible***

Its made of a new rubber-plastic material that's tough, resilient, suitable for handling most acids and alkalis. 3-gal. size. Easy-pour, drip-proof spout. Also 1-qt. and 2-qt. dippers, hard rubber bottles, etc. Write for name of nearest dealer.

**ACE rubber and plastic products**

**AMERICAN HARD RUBBER COMPANY**

**93 WORTH STREET • NEW YORK 13, N. Y.**

this little drip costs you money!

On a 10¢-per-gallon product, 6 CC of leakage per minute costs you about $90 per yedr in unnecessary product waste.

**REPLACE PUMP PACKING WITH**

# BJ mechanical seals

Eliminate unnecessary stuffingbox leakage by installing a BJ Mechanical Seal. You not only realize important savings of pumped products but you also save on repacking and downtime losses. A BJ Mechanical Seal also prevents contamination of the pumped liquid ... protects against volatile and corrosive liquid hazards.

**BJ MAKES A COMPLETE LINE OF MECHANICAL SEALS...**

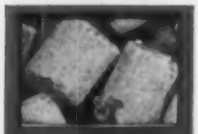
BJ makes reliable high-precision seals in material and construction combinations to answer almost any pressure, temperature and liquid requirements. This means that BJ can provide the *one best seal* for each specific pumping need. Ask your nearest BJ sales engineer to show you how Mechanical Seals can save you money. Or you can obtain further information by writing for BJ Bulletin No. 54-1-10,000.

BJ
SINCE 1872

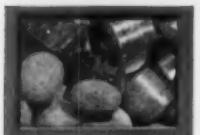
**Byron Jackson Co.**
PUMP DIVISION
P. O. BOX 2017 TERMINAL ANNEX • LOS ANGELES 54, CALIF.
*Sales Offices in Principal Cities*

HOW YOU BENEFIT WITH GIRDLER CATALYSTS

CUSTOM DESIGN matches YOUR needs


TECHNICAL SERVICE helps you save

QUALITY CONTROL assures uniformity


MODERN FACILITIES produce economically


GIRDLER RESEARCH gives you the best . . . always

**Increases ammonia output 40% with**

# GIRDLER G-29 CATALYST

*at Mississippi Chemical Co., Yazoo City, Miss.*

**APPLICATION:** Promoting reaction of steam, air and natural gas in reforming furnaces to produce ammonia synthesis gas.

**TECHNICAL SERVICE** of Girdler demonstrated that a switch to its newly developed G-29 would result in an appreciable increase in the ammonia production.

**RESULTS:** Greater activity of G-29 enables customer to increase ammonia production about 40% when required. This is accomplished with no appreciable increase of fuel consumption per unit of ammonia produced.

Find out how Girdler Catalyst Technical Service can help *you!* Write for Bulletin G-260.

the GIRDLER Company

A DIVISION OF NATIONAL CYLINDER GAS COMPANY
LOUISVILLE 1, KENTUCKY

GAS PROCESSES DIVISION: New York, San Francisco
VOTATOR DIVISION: New York, Atlanta, Chicago, San Francisco
*In Canada:* Girdler Corporation of Canada Limited, Toronto

## NOTED AND QUOTED

(*Continued from page* 14)

and plastics, isobutylene for butyl rubber, and for other derivatives . . .

Henry G. McGrath
Address before New York Petroleum Section, A.I.M.E.

## MARGINAL NOTES

**Electrometric pH Determinations—Theory and Practice, Roger G. Bates. John Wiley & Sons, Inc., New York (1954), 331 pages, $7.50.**

*Reviewed by John E. Leonard, Beckman Instruments, Inc., Fullerton, Calif.*

This book is a modern treatment of the whole field of *p*H theory and instrumentation in one volume, and its author is one of the leading authorities in the field.

The first six chapters are particularly interesting, dealing with the fundamental thermodynamic principles of *p*H, definition of *p*H scales, establishment of *p*H standards, definitions of liquid junction potentials and ion activities with a clarity and conciseness seldom found in the texts of electrochemistry.

The remaining four chapters are a well-organized summary of the properties of electrode systems, their structures. functions, and limitations. The *p*H meter is discussed from the standpoints of operation and construction. Commercially available meters are surveyed, with attention to the various different design features they present. Accessory equipment, such as electrodes, flow and immersion assemblies, and recorders, is described and a brief treatment of a few actual process control problems is included.

For the engineer who is interested in understanding the basic principles involved when *p*H instrumentation is applied to process control, the book would be an excellent investment.

**Chemical Industry Facts Book. Manufacturing Chemists' Association (1955), 160 pages, $1.00.**

This reference source (second editon) contains 15 chapters ranging from "What the Chemical Industry Makes" to such specifics as "Chemicals and Health" and "Chemicals in Defense." This editon offers an additional 52 pages of information over the first edition.

(*More Marginal Notes on page* 30)

# high quality product

*boost average ratings as much as 2 octane numbers with the*

## *Ljungstrom® Air Preheater*

With waste heat recovered and returned to the furnace in combustion air, the most modern heat-transfer systems can be operated at peak efficiency.

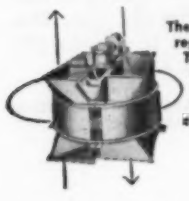
That's why you boost product quality with the Ljungstrom Air Preheater. It's heat-recovery efficiency makes possible advanced furnace designs that assure remarkably close control of processing. And finer control means a more uniform product . . . with average ratings as much as 2 octane numbers higher. One still's added income just from higher product quality is $58,000 annually.

HOW FAST IS "WRITE-OFF"?

In earnings from higher octane ratings, many refiners write off the cost of the Ljungstrom installation in less than two years. This time is cut to *nine months and even less*, when the other Ljungstrom advantages are taken into account — saves up to 20% in fuel costs . . . permits more economical furnace design, with no need for convection surfaces . . . burns many fuels you used to throw away . . . results in consistently higher through-put . . . and minimizes slag.

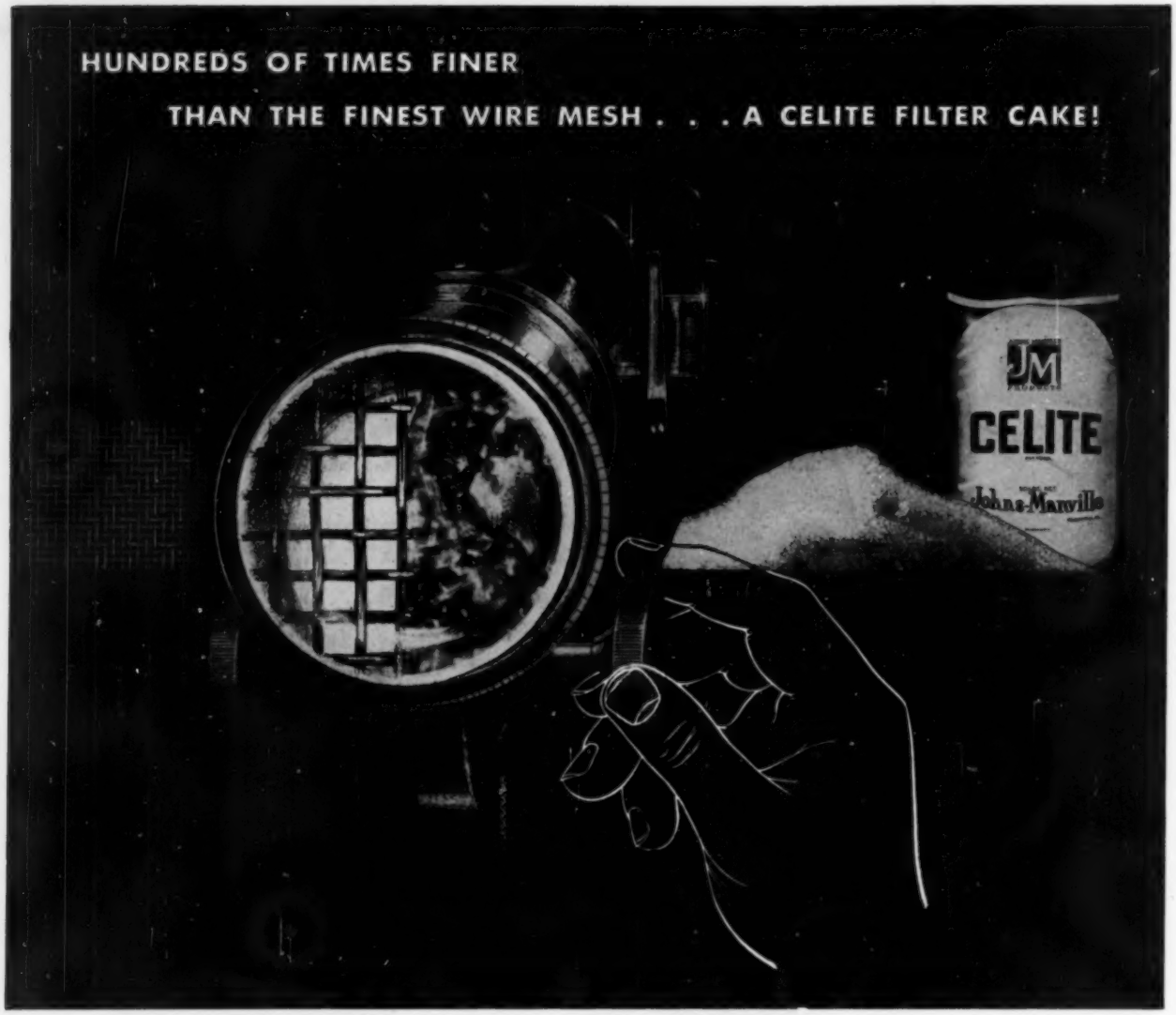
For more complete details on what the Ljungstrom Air Preheater can do for you . . . for an analysis of the heat recovery benefits obtainable in fuel burning equipment — call or write The Air Preheater Corporation.

*Wherever You Burn Fuel, You Need Ljungstrom*



The Ljungstrom operates on the continuous regenerative counterflow principle. The heat transfer surfaces in the rotor act as heat accumulators. As the rotor revolves, the heat is transfered from the waste gases to the incoming cold air.

**The Air Preheater Corporation** 60 East 42nd Street, New York 17, N. Y.




## with Celite Filtration you are assured perfect clarity

HERE is a clarification method which can remove even the finest suspended solids . . . a Celite* Filter Cake contains more than 2,500,000 filter channels per square inch of surface. Here, too, is a method so flexible that it permits the right balance of fast flow rate and high capacity, with the degree of purity and clarity required.

Celite powders may be used with any type of conventional filter. Only 2 simple steps are required. First, a "pre-coat" of Celite is deposited on the filter medium. Second, small amounts of Celite are added to the solution, to form a continuously fresh filter surface. To meet different filtration requirements, Celite is available in nine standard grades of microscopically controlled particle size. Utmost uniformity is assured by exclusive processing techniques.

The extraordinary efficiency and flexibility of Celite Filtration have made it the standard for entire industries. For perfect clarity in food products such as jellies, sugar, wine, beer . . . for highest purity in antibiotics . . . for removal of impurities from chemicals, petroleum, dry cleaning solvents . . . Celite offers unequalled advantages.

If you want to improve your present filtration system or find an economical way to utilize filtration in your processing, investigate the Celite method now. One of the Johns-Manville Celite Filtration Engineers will gladly discuss your problem. These men are backed by complete technical services and the Johns-Manville Research Center, largest laboratory of its kind in the world. For further information write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

*Celite is Johns-Manville's registered Trade Mark for its diatomaceous silica products.

JM PRODUCT

**Johns-Manville CELITE FILTER AIDS**

# the valve that LIKES TO BE COMPARED

## Is a valve positioner always required?

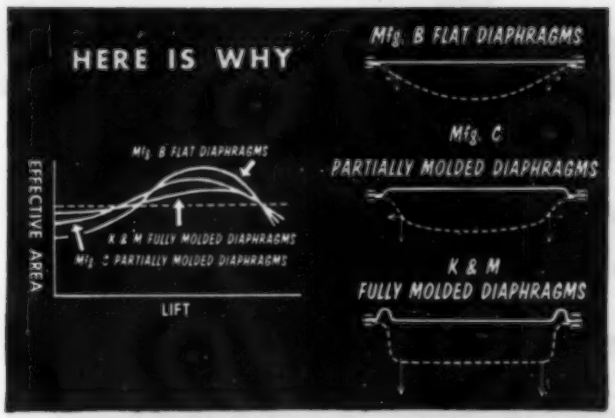
K & M provides 20-40% less positioning error. Often the need for a valve positioner is eliminated . . . because the K & M *fully* molded diaphragm gives the most constant effective diaphragm area.

K & M precision positioning also derives from long stem travel . . . lift that equals or exceeds any comparable valve . . . plus the highest power factor in the industry.

Behind it all lies one fact: K & M Control Valves are not *adapted* to high lift, they are *designed* for it. Throughout the entire range of valve travel . . . positioning is accurate and undistorted . . . control increments are finer with minimized positioning error.

Write for the K & M Valve Data Catalog, Bulletin CV-53.

***77th Anniversary . . . Oldest U. S. Pressure and Level Control Valve Manufacturer***




**With K & M *fully molded* diaphragms, virtually all components of force are vertical. Added to this, K & M gives the highest power factor (diaphragm area x lift) for precise valve positioning.**

diaphragm control valves

**KIELEY & MUELLER, INC.**

**64 GENUNG STREET, MIDDLETOWN, NEW YORK**

K&M

# POSITIVE PERFORMANCE

An important cost reduction factor in the production of chlorine and caustic soda is the positive performance of GLC ANODES.

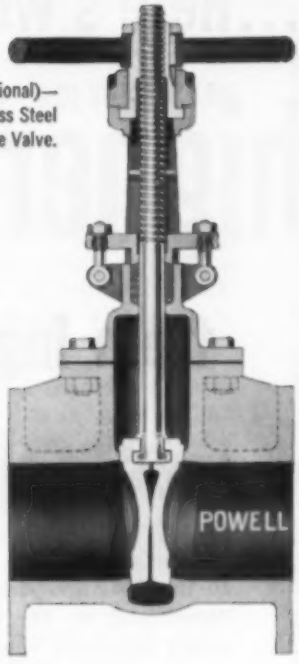
ELECTRODE GLC DIVISION

Great Lakes Carbon Corporation

GRAPHITE ELECTRODES. ANODES. MOLDS and SPECIALTIES

**ADMINISTRATIVE OFFICE:** 18 East 48th Street, New York 17, N.Y.
PLANTS: Niagara Falls, N.Y., Morganton, N.C.
OTHER OFFICES: Niagara Falls, N.Y., Oak Park, Ill., Pittsburgh, Pa.
SALES AGENTS IN OTHER COUNTRIES: Great Northern Carbon & Chemical Co., Ltd., Montreal, Canada
Overseas Carbon & Coke Company, Inc., Geneva, Switzerland; Great Eastern Carbon & Chemical Co., Inc., Chiyoda-Ku, Tokyo, Japan

FIG. 2453 DG (Sectional)—
150-Pound Stainless Steel
O. S. & Y. Gate Valve.




# Performance-- Value...

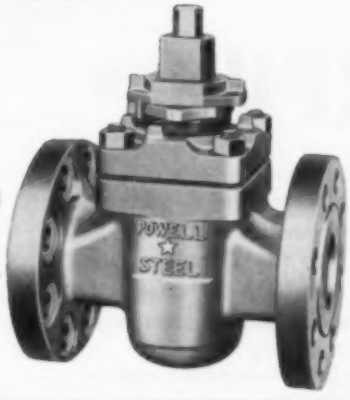
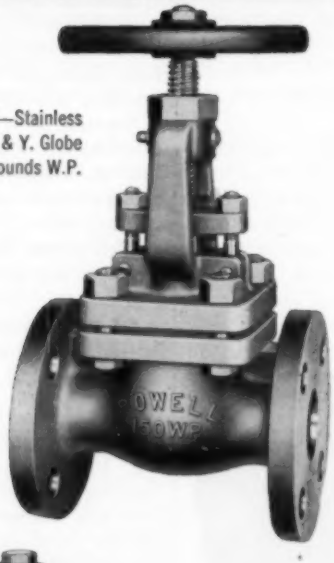



Fig. 1559—150-Pound Steel
Lubricated Plug Valve.

**. . . POWELL VALVES . . . THE COMPLETE QUALITY LINE . . . POWELL VALVES . . .**

FIG. 2475—Stainless
Steel O. S. & Y. Globe
Valve For 150 Pounds W.P.



# Powell Valves

FIG. 2342—Stainless
Steel Bolted Cap Swing
Check Valve For 150
Pounds W.P.

You can depend on outstanding *performance* from every valve made by The Wm. Powell Company, for Powell Valves have a proven record of long life and dependable service.

And Powell Valves give you better *value!* They're precision made and incorporate many quality features—features that can save you money and give you lasting flow control.

Consult your Powell Valve distributor. If none is near you, we'll be pleased to tell you about our *COMPLETE quality line*, and help solve any flow control problem you may have.

**The Wm. Powell Company, Cincinnati 22, Ohio . . . . . 109th year**

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# higher efficiency

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1. Better design of pump impellers, casing volutes and inlet and discharge passages assure maximum capacity.
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## MARGINAL NOTES

(*Continued from page 24*)

**Adhesion and Adhesives—Fundamentals and Practice. Edited by F. Clark, J. E. Rutzler, and R. L. Savage. John Wiley & Sons, Inc., New York, N. Y. (1954), 229 pages, $9.75.**

*Reviewed by J. O. Hendricks, Manager of Research, Tape Division, Minnesota Mining & Manufacturing Co., St. Paul, Minn.*

This book is a collection of papers which was presented at a symposium held at Case Institute of Technology, Cleveland, Ohio, and at a conference held in London, England. It is divided into two parts–fundamentals and practice. There are fourteen papers under the first heading and twenty-nine papers under the second. The book will be of value to those interested in the theoretical aspects of adhesion and those concerned with the applications of adhesives.

The theoretical portion contains papers which are worthy of study. A number of them treat the adsorption of gases and liquids on solid surfaces. Two papers go into the theory of solid-to-solid adhesion and these present a foundation on which others may build. The fundamental papers either by content or reference present the state of the science of adhesion as it has been developed.

As indicated by the number of papers, there is more known and the art has been developed further with regard to practical adhesives and application than is the case with respect to fundamentals of adhesion. Practically all types of adhesives are discussed together with the applications of joining together a variety of materials.

This should be included in any adequate library covering this subject.

**A.S.T.M. Proceedings. American Society for Testing Materials, Philadelphia, Pa. (1954), 1,400 pages, $12.00.**

This volume includes many technical reports and papers and a Summary of the Proceedings of the 57th annual meeting held in June, 1954, listing by title and author the program for each of the thirty-six sessions. In addition the table of contents lists all symposiums published separately as Special Technical Publications and all papers published in the A.S.T.M. Bulletin.

## Books Received

**The Elements of Chromatography. T. I. Williams. Blackie & Son, Ltd., London, and Philosophical Library, Inc., New York, N. Y. (1955) 90 pages, $3.75.**

**Organic Reactions. Vol. VIII. Editor-in-Chief Roger Adams. John Wiley & Sons, Inc., New York, N. Y. (1954), v-viii+437 pages, $12.00.**



Cross Chemical Company Selects

## CEP trends / POLYETHYLENE

**While plant capacity for polyethylene** plastic has been mounting by leaps and bounds, there has been a good deal of excitement in the industry over new low pressure processes for making the resin. Present polyethylene requires up to 15,000 pounds pressure or higher, whereas 600 pounds or less is required with the new method.

Phillips Chemical Co. has developed its own process, still secret—and has applied for patents. The Phillips product, Marlex, is more rigid and considerably more heat resistant than the original type, is being pushed by an extensive advertising campaign.

On the other side of the picture Koppers Co. is producing a low pressure resin under the name of Dylan. Bakelite division of Union Carbide & Carbon Corp. is working on low pressure poly on a pilot plant scale. Both the latter are understood to have licenses under the patents of Karl Ziegler of the Max Planck Institute of Berlin and several other firms have also taken out licenses. The Ziegler process works by means of a catalyst as, presumably, does the Phillips process.

**At first sight** some people jumped to the conclusion that a low pressure process might supercede the very high pressure processes now used, that over the long range it might make obsolete the huge present capacity in high pressure polyethylene.

However, there is no indication that this is likely. Present important makers of polyethylene say that the new resin is "a very interesting new product," but that it is simply another new and useful plastic that will open new markets, will not replace the present polyethylene. Also, at least at the start, the low pressure poly is expected to cost around 10 cents a pound more than high pressure poly and the prices of high pressure poly are coming down. Present price is 41 cents a pound, with some grades selling for 35 cents a pound. Some in the trade look for a price of 30 cents before the end of the year. Even lower prices are seen in the future.

The greater rigidity of the new type of poly means a number of interesting new markets which would not mind paying the higher prices. Toy industry is one possibility, pipe another. The new material may find fields of competition with rubber, styrene.

Work on treating polyethylene with gamma radiation continues both in universities and industrial laboratories. It produces a material which is stiffer, stronger and withstands more heat. General Electric Co., which appears to be farthest along in commercial development of this work, is offering sheets to be used chiefly for electrical insulation. Cost of the sheets is still high—65 cents a square yard.

**Growth of conventional polyethylene** has been sensational. Production around the first of this year was at the rate of 250 million pounds annually. By the end of the year production is expected to be running at the rate of over 400 million pounds. In 1956 capacity will be up to over 500 million pounds.

Leader in the field is Union Carbide & Carbon's Bakelite division which has three plants in operation each with a capacity of 60 million pounds yearly. A fourth plant on the west coast will begin operation some time early in 1956. Du Pont is an important producer, with about 100 million pounds capacity.

Newcomers to the field are Spencer Chemical (45 million pound plant), Monsanto Chemical (60 million pounds), National Distillers (26 million pounds), Eastman Kodak (about 20 million pounds), and Dow Chemical (about ready to come in with a 25 million pound plant). Allied Chemical & Dye produces polyethylene waxes but not the plastic.

Although poly started as an electrical insulating material and then moved into household wares, its biggest and fastest growing use is in sheeting for packaging. This market is now estimated to take around 75 million pounds annually. Housewares come second with a consumption of around 40 million pounds. Pipe, produced and distributed by some of the steel firms, is the third largest market and is growing fast. Last year it consumed around 32 million pounds. Wire and cable insulation takes about 30 million pounds and paper coating about 24 million pounds.

The industry is confident that the market will absorb its huge output, even though there may be some headaches for sales forces for a while. The probable down trend in prices is expected to open new fields.

**Huge opportunities** are seen in the food packaging field which last year took nearly twice as much film as it did in 1953, and nearly three times consumption in 1952.

An estimated 70 billion pounds of fresh farm products are sold in the United States yearly, of which less than 15% are packaged. Losses in retail stores from spoilage are high, packaging in film could be a lifesaver for the retail trade, particularly in competition with the growing frozen food business.

Builders lately have had the idea of wrapping a building under construction in polyethylene film. This means that construction, the laying of mortar and plaster, can go on even in bad weather, so labor does not have to stop during periods of rain or snow. How large this and other building uses might become cannot be estimated as yet, but they may well be important.

Polyethylene is now competing with cellophane as a wrapping, but the trend appears to be for the joint use of the two products, using the polyethylene to coat cellophane film.

# Grace Chemical Company Selects an Air Products INCORPORATED AIR SEPARATION PLANT

GRACE CHEMICAL COMPANY
3 HANOVER SQUARE, NEW YORK 4, N. Y.

W. R. GAGE
PRESIDENT

March 1, 1955

Mr. C. R. Anderson, Vice President
Air Products, Incorporated
P. O. Box 538
Allentown, Pennsylvania

Dear Mr. Anderson:

The Grace Chemical Company's new anhydrous ammonia-urea plant at Memphis, Tennessee has been "on-stream" now for some time. The successful operation of the equipment is in no small part due to the manner in which the air separation unit has functioned.

The low-temperature equipment supplied by your company was erected under the supervision of your engineering staff with a very minimum of difficulty. The presence of your men during the plant "shake-down" period contributed greatly to our starting production with less delay than normally is to be expected on a project of this size.

Very truly yours,
GRACE CHEMICAL COMPANY
W. P. Gage

WPGsew

Air Products Air Separator in Grace Chemical Company's new ammonia plant.

Grace Chemical Company, subsidiary of W. R. Grace and Company, has started operations at its new anhydrous ammonia-urea plant at Memphis, Tennessee. The new plant was constructed to put this century-old firm into the relatively new agricultural chemical field on a large scale. Production is expected to exceed the rated capacity of 90,000 tons of ammonia and 54,000 tons of urea annually.

An important unit in the process is the air separation plant designed and built by Air Products, Inc. to split air into nitrogen and oxygen. Air Products has built over 700 air separators which are being operated successfully throughout the world.

Satisfaction, from the initial inquiry to the successful operation of the plant, is assured when your low-temperature processing work is entrusted to Air Products.

If your project calls for gas separation by low-temperature processing, get in touch with us.

36-page brochure discusses the broad possibilities of low-temperature processing and describes Air Products' facilities. Write for a free copy.

Air Products INCORPORATED

Dept. U, Box 538, Allentown, Pa.

**Specialists in Low-Temperature Processing**

# CEP what's in this issue...

## you may be interested in—

LOW PRESSURE POLYethylene is on the minds of many . . . Why, asked a friend the other day, have so many high pressure (1,500-2,500/lb./sq. in.) plants been built, when it looks like low pressure plants are "right around the corner?" To get the answer to this and other questions on low pressure poly, read TRENDS . . . p. 31.

WHICH PROFESSIONAL SOCIETY is having its 75th anniversary . . . once had Thomas A. Edison as its president? Also, do you know what will in the final analysis control your access to nuclear information under the new "need to know" program? See Opinion & Comment . . . p. 249.

POLYETHYLENE FABRICATION techniques - (p. 251) offer the chemical engineer a means for making or having made equipment with excellent physical and chemical properties.

HOW'S YOUR ORGANIZATION? - (p. 257) is by a seasoned executive who believes in getting results . . . In this, you'll find ideas as to how to set up working relationships - and how to make them work...

URANIUM PRODUCTION METHODS REVEALED! - (p. 261) The process and much of the equipment used at the Monticello, Utah uranium mill are described . . .

HYDROGEN'S ATTACK ON STEEL and other metals - (p. 266) has over the years produced mysterious failures, some serious ruptures . . . Now Institute president Dodge and associate Van Ness have completed a study of the conditions under which this can happen, and they conclude, "hydrogen at pressures as low as 2,000 atm. can cause dangerous embrittlement of metals even at room temperature."

CENTRIFUGAL EQUIPMENT selection - (p. 272) is written about by an Ethyl Corp. process engineer -- which means that he goes about it from the approach of the job to be done, vs. the equipment which has been found suitable through experience . . .

THERE ARE EVAPORATORS and evaporators - (p. 279) but we think you may be interested in quite a special type -- a turbulent-film model, which has been used by the authors for concentrating GR-S latex . . .

FILTRATION - (p. 282) has often been termed one of the most widely used chemical engineering unit operations . . . In this definitive article, author Tiller covers part II of a fundamental concept development, which is intended for men in industry who are interested in getting away from the old empirical concepts of filter selection . . .

AGGLOMERATION - (p. 291) just in case we've caught you with your nomenclature slightly behind the times . . . refers to making bigger things out of little ones . . . This paper reports on observations translatable over into products having no resemblance to fertilizers - for end use, that is . . .

VACUUM-BRAZED CLAD METAL - which many feel will revolutionize the materials-of-construction picture for the chemical engineer concerned with designing, procuring and building chemical process equipment - is described as part of a round-up report on some late news of interesting materials developments . . . You'll also find a report on ELECTRO-DEPOSITION and ELECTRO-LESS DEPOSITION of nickel inside process vessels and pipe . . . also a remarkable new process for electro-depositing CHROMIUM DIRECTLY ON STEEL, for plating the insides of vessels. See page 35.

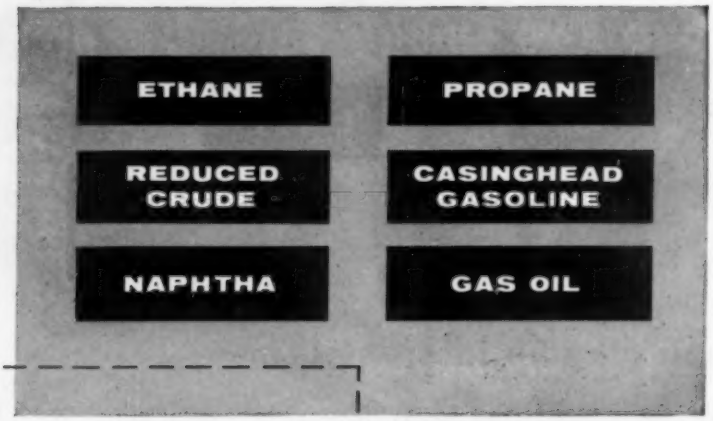
WHAT THE PROFESSIONAL chemical engineer really wants is cited by author-Institute V.P. Art Doolittle of Carbide . . . in a stirring article on "Essential Characteristics of Professional Conduct"...p. 40.

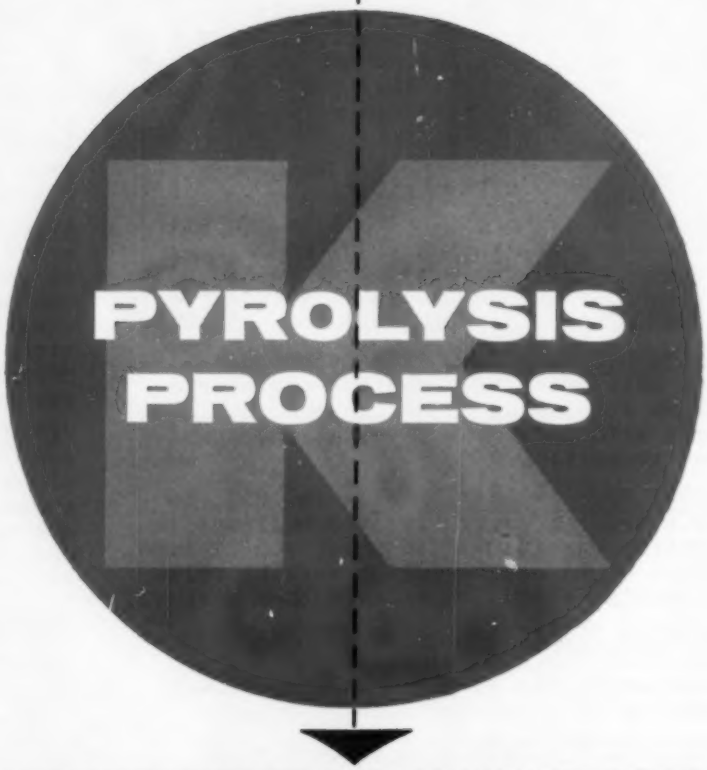
NIONEL - pardon our use of a trade name - but how would you refer to a brand new stainless steel that has unusual corrosion resistance properties? Part II of a series of 3 reference sheets begins to unfold the corrosion resistance properties . . . p. 296.

INDUSTRY SPONSORED "SCHOOLS" - for industrial chemical engineers and professors - are reported on in a personal-experience resume by one who attended two of them in recent weeks . . . p. 44.

— J. B. M.

# WHATEVER THE FEEDSTOCK FOR ETHYLENE




In ethylene manufacture, process engineering by The M. W. Kellogg Company offers many advantages over conventional systems, and guarantees optimum yields and purity from economically available feed stocks.

The key is M. W. Kellogg's steam-pyrolysis process. Used successfully in England for the cracking of heavy naphtha, it permits ethane and propane pyrolysis plants to be designed for higher yields; makes possible the economic production of ethylene and other olefins from casinghead or natural gasoline, residuals, and other low-value products; and indicates that even crude oil can be economically processed to a maximum of olefins instead of to gasoline.

M. W. Kellogg's steam-pyrolysis results have been marked by excellent yields of high purity olefins, generally higher than can be obtained by conventional cracking. This is due largely to the Kellogg process following cracking, where the stream is separated and purified in a low-temperature, low-pressure fractionation system.

Equally important, is the remarkable high on-stream efficiency which permits continuous plant operation at high conversions without the need for spare cracking furnaces.

The M. W. Kellogg Company has accumulated considerable cost data on ethylene manufacture, based on pilot plant and actual commercial production. Interested firms are invited to review these data with M. W. Kellogg chemical process engineers. *Write for new 8-page folder.*

## KEY TO BETTER YIELDS AND HIGHER PURITY

M W KELLOGG

**PETROCHEMICAL PROCESSES AND PLANTS**

**CHEMICAL PROCESS DIVISION**

**THE M. W. KELLOGG COMPANY, 225 BROADWAY, NEW YORK 7, N. Y.**

*The Canadian Kellogg Company, Limited, Toronto • Kellogg International Corporation, London*

SUBSIDIARIES OF PULLMAN INCORPORATED

CEP

# opinion and comment

### The Need to Know

The Atomic Energy Commission announced recently a new program which would give general access to restricted data on nuclear matters. The program is the implementation of the so-called "gray area," under which nonmilitary information classified as "confidential, restricted" is made available to any person who can prove a need to know in his business, profession, or trade. The only conditions necessary to obtain such atomic data are a simplified security, or L, clearance and an agreement to conform with A.E.C. security regulations.

We welcome this further step of the Atomic Energy Commission in making necessary data available to industry and individuals. We hope the program works. More, we believe that it will work, but it may not be amiss now to point out that its success does not depend upon the public, upon the simplified security clearance, or upon written agreement to abide by the A.E.C. security regulations. Its success rests with the A.E.C. If the agency is willing to make available quantities of important confidential, restricted data, then industry and commerce will benefit. If, however, the A.E.C. places in the secret, restricted data file most of the data formerly marked as confidential, restricted these then will not become available to L-cleared persons. Under both the previous Atomic Energy Act and the Atomic Energy Act of 1954, the determination of what information can be made available to our citizens, to our industry, rests squarely with the commissioners themselves. All that is needed is the willingness to declassify such material. This was the case prior to the "gray-area" concept, this is the case now, and it will always be the case as long as secrecy surrounds nuclear matters.

### Congratulations, A.S.M.E.

The American Society of Mechanical Engineers is celebrating its 75 Anniversary. Founded in 1880, the organization has grown to 40,000 members with chapters all over the United States and in one hundred and thirty-six colleges and universities. The good that the American public has received from the activities of this Society can probably never be evaluated and certainly will not be accorded in the public mind its full measure of credit.

The mechanical engineers are responsible for many of the codes and standards upon which industry builds today—as a matter of fact the activity of the A.S.M.E. in codes and standards gave rise to the present American Standards Association. Its work on the boiler code has practically eliminated the explosion of boilers in the United States. In 1900 boilers were exploding at a rate of 1,300 a year.

The society has been headed by many of the most famous mechanical engineers in the United States, and its members today are carrying on a proud tradition. The names of the great men who became identified with the society is an engineering roll of honor—Edison, Westinghouse, Steinmetz, Sperry, Orville Wright, Warner and Swasey, Babcock and Wilcox, Hoe, plus many more whose achievements are legendary.

Sincere congratulations to the A.S.M.E. on its 75 Anniversary.

F.J.V.A.

# INTALOX

## The Unique SADDLE PACKING for GREATER TOWER EFFICIENCY LOWER COST

*Unretouched View of an Irrigated Tower Section Photographed through a Glass Tower.*

The surface area of the packing in a column that is in contact with both liquid and gas is the only surface area that counts. Packings that "nest" or "pattern pack" have a low ratio of effective area to actual area. Pressure drops rise, flooding limits lower.

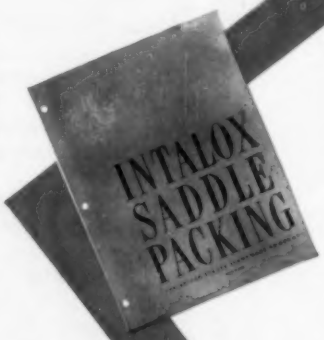
Examine the photograph above. There is no blocking of surface area there. The unique design of Intalox makes certain that no two pieces of Intalox can nest or cover each other to such an extent that any significant portion of the packing surface is rendered ineffective.

This greater randomness in a packed bed means better packing performance — greater tower efficiency at lower cost.

**U. S. STONEWARE**

**Akron 9, Ohio**

**WRITE FOR THIS NEW 16-PAGE BOOKLET ON INTALOX SADDLE PACKING**




*This new booklet (Bulletin S-29) gives detailed comparative data on the relative efficiencies of various packings — shows how Intalox Saddles can help you reduce tower heights, lower gas pumping costs, or obtain greater capacity from your present tower. Free on request. Write*

THE U. S. STONEWARE CO.
Akron, Ohio

358D-1

**TYPICAL DATA ON INTALOX* SADDLE PACKING**

| Nominal Size, Inch | Approximate Number per Cu. Ft. | Approximate Weight per Cu. Ft., Lb. | Approximate Surface Area Sq. Ft./Cu. Ft. | Percent Free Gas Space | Equivalent Spherical Diameter Dp, Inch |
|---|---|---|---|---|---|
| ¼ | 117500 | 45 | 300 | 75 | 0.20 |
| ½ | 20700 | 41 | 190 | 78 | 0.32 |
| ¾ | 6500 | 40 | 102 | 77 | 0.48 |
| 1 | 2385 | 38 | 78 | 77.5 | 0.68 |
| 1½ | 709 | 35 | 59.5 | 81 | 0.96 |
| 2 | 265 | 38 | 36 | 79 | 1.38 |

**Trade name, The U. S. Stoneware Co.*

# plastics

## FOR CHEMICAL ENGINEERING CONSTRUCTION

# polyethylene

*Frank J. Bockhoff* — Fenn College, Cleveland, Ohio

*Richard F. Roth* — American Agile Corporation, Maple Heights, Ohio

During the past eight years polyethylene has been playing an increasingly important role as a material of construction in the chemical processing industries. Factors influencing its use are ease of fabrication (by the hot-gas welding technique), chemical resistance, and excellent impact strength.

When polyethylene was released for civilian use shortly after World War II, engineers were quick to recognize its many outstanding physical and chemical properties. It has replaced such materials as lead, tin, copper, and stainless steel in many applications.

In the chemical and allied industries polyethylene fabrications and moldings are used extensively for acid tanks, handling and storage vessels, self-supporting duct lines, centrifugal fans, valves, piping, dipping baskets, and fabricated containers of various sizes and shapes.

Of particular interest to the chemical engineer is the inertness of polyethylene to hydrofluoric acid in various concentrations. Figure 1 shows a television-tube washing and etching tub in which hydrofluoric-acid resistance is of paramount importance. The corrosion resistance of polyethylene allows it to outlast metallic alloys previously used in this application.

The present monthly consumption of polyethylene is in the neighborhood of 16 to 17 million pounds, and reasonable estimates (*1*) indicate that the average monthly consumption for 1955 will be 25 million pounds.

The unique properties of polyethylene make it a particularly desirable material for the construction of chemical-process equipment. It is tough at extremely low temperatures and retains this toughness through a wide temperature range. Excellent dielectric properties and lightness in weight make the material applicable for electrical insulations of various types. Its low moisture-vapor transmission and good tear strength contribute to its popularity as a moisture barrier.

### Structure

In molecular structure polyethylene is esentially a long straight-chain paraffin having from 1,000 to 3,000 $-CH_2$ groups per molecule. The presence of a slight amount of olefinic structure and branching has been shown. These small discontinuities in the otherwise linear structure are important to some of the desirable properties of polyethylene. Typical of paraffins, polyethylene is chemically inert in most environments.

Polyethylene exhibits a considerable degree of microcrystallinity. It is roughly 60% crystalline at room temperature. The amorphous-crystalline nature of

Fig. 1. Etching tub, ½-in. thick polyethylene, for handling hydrofluoric acid and alkaline cleaners, 3 years life to date.

**Table 1.—Typical Properties of Structural Grade Polyethylene (Agilene)**

| Property | | A.S.T.M. | Value | Units |
|---|---|---|---|---|
| Tensile strength | —70° F. | D638—52T | 4,750 | lb./sq.in. |
| | 73° F. | D638—52T | 1,900 | lb./sq.in. |
| | 158° F. | D638—52T | 950 | lb./sq.in. |
| Elongation | —67° F. | D412—51T | 60 | % |
| | 73° F. | D412—51T | 600 | % |
| | 158° F. | D412—51T | 600 | % |
| Modulus of elasticity | 73° F. | D638—52T | 35,000 | lb./sq.in. |
| Stiffness | —67° F. | D747—50 | 230,000 | lb./sq.in. |
| | 73° F. | D747—50 | 27,000 | lb./sq.in. |
| | 158° F. | D747—50 | 8,000 | lb./sq.in. |
| Shear strength | 73° F. | D732—46 | 2,750 | lb./sq.in. |
| Impact strength, Izod. | —40° F. | D256—47T | 0.8 | ft.lb./in. |
| | 73° F. | D256—47T | did not break | ft.lb./in. |
| Hardness Shore | | D676—49T | C81. D48 | |
| Thermal conductivity | | Cenco-Fitch | 1.75 | B.t.u./(hr.)(sq.ft.)(° F./in.) |
| Softening point, Vicat | | | 201 | ° F. |
| Brittleness temperature | | D746—51T | < —105 | ° F. |
| Flammability | | D635—44 | 0.94 | in./min. |
| Dielectric constant, 60 cycles to 100 megacycles | | D150—47T | 2.3 | |
| Power factor, 60 cycles to 100 megacycles | | D150—47T | 0.0005 | |
| Specific gravity | | D792—50 | 0.92 | |
| Water-absorption | | D570—42 | 0.014 | % |

polyethylene imparts greater strength to the material and contributes to such desirable properties as ductility.

Usable commercial grades of polyethylene vary from 10,000 to 50,000 mole wt. with most of the material falling in the 20,000 to 30,000 mole wt. range. Higher molecular-weight materials are desirable from both a physical-property and a chemical-resistance standpoint.

### Mechanical Properties

Distinguishing properties of polyethylene, when compared to other plastic materials, are its flexibility and its impact strength. Flexibility is achieved without the addition of plasticizer. There is, then, no danger of dimensional instability due to loss or migration of plasticizers. In addition, toxicity hazards due to plasticizers are nonexistent. This is of particular interest to the food industry.

General properties of structural-grade polyethylene are given in Table 1. Polyethylene is used where chemical resistance combined with toughness, flexibility, and lightness in weight are desired. The impact strength of polyethylene is so high that the material cannot be broken on standard testing machines at room temperature. Polyethylene is an invaluable material of construction in those installations in which shock or vibration is encountered.

**Table 2.—Chemical Resistance of Structural Grade Polyethylene (Agilene), Particularly Corrosive Environments**

| | Reagent | Time and Temperature | | Weight Increase | Tensile Loss in Strength | Loss in Elongation at break |
|---|---|---|---|---|---|---|
| % | Acid | | | (%) | (%) | (%) |
| 25 | sulfuric | 3 months at 20° C. | | 0.1 | None | None |
| 50 | sulfuric | | | 0.1 | None | None |
| 80 | sulfuric | | | 0.1 | None | None |
| 98 | sulfuric | | | 0.1 | None | None |
| 36 | hydrochloric | | | 0.1 | None | None |
| 25 | nitric | | | 0.1 | None | None |
| 50 | nitric | | | 0.3 | None | None |
| 80 | nitric | | | 1.9 | 10 | 40 |
| 95 | nitric | | | 6.9 | 20 | 75 |
| 25 | chromic | | | 0.1 | None | None |
| 98 | phosphoric | | | 0.1 | None | None |
| | formic | | | 0.1 | None | None |
| | citric (conc.) | | | 0.1 | None | None |
| | lactic | | | 0.1 | None | None |
| 30 | caustic soda | | | 0.1 | None | None |
| 50 | nitric | 1 month | 40° C. | 1.9 | 30 | 55 |
| 25 | sulfuric | | 60° C. | 0.1 | None | None |
| 50 | sulfuric | | | 0.1 | None | None |
| 80 | sulfuric | | | 0.1 | None | None |
| 25 | nitric | | | 0.5 | 5 | 10 |
| 50 | nitric | | | 7.5 | 50 | 70 |
| 80 | nitric | 1 week | | 17.5 | 90 | 100 |
| 36 | hydrochloric | 1 month | | 0.1 | None | None |
| 98 | phosphoric | | | 0.1 | None | None |

### Electrical Properties

The initial spur in the side of American production of this material was the need for suitable insulating materials for radar applications. The electrical properties of polyethylene are outstanding—low dielectric loss, low conductivity, and high dielectric strength. These properties, coupled with its mechanical properties, make it suitable as a dielectric for many applications. Polyethylene is an insulator for electric power supplies at both domestic and transmission voltages. The water absorption of polyethylene is so low that these electrical properties are not appreciably affected by humidity.

Antioxidants are incorporated in certain grades of polyethylene to prevent damage to power-loss characteristics during molding or extrusion operations.

### Chemical Properties

At room temperature polyethylene is unaffected by most corrosive reagents and has no known solvent. Hydrochloric, sulfuric, nitric, and hydrofluoric acids can be handled conveniently with this material. Concentrated caustics, such as ammonium hydroxide, potassium hydroxide, and sodium hydroxide do not affect polyethylene. Dilute aqueous acids, bases, and salts can be handled effectively without the slightest corrosive indication.

**Polyethylene is not attacked by oxidizing chemicals such as potassium permanganate or hydrogen peroxide (30%) at room temperature. Slow oxidation may occur at higher temperatures.**

**Liquid and gaseous halogens attack polyethylene slowly in the cold but more rapidly at higher temperatures, and may cause discoloration accompanied by a slight change in properties. However, polyethylene is used successfully in fluorine and hydrofluoric acid installations at normal temperatures.**

**Table 2 gives typical results of chemical resistance tests for structural-grade polyethylene under particularly corrosive conditions.**

## Solvent Resistance

The only common solvents which will affect polyethylene at room temperature are the chlorinated hydrocarbons, such as carbon tetrachloride and ethylene dichloride, and aromatic and aliphatic hydrocarbons. These materials, although they do not dissolve polyethylene, tend to swell the plastic and permeate thin films.

At temperatures above 70° C. polyethylene can be dissolved by several common solvents including xylene, toluene, amyl acetate, trichloroethylene, petroleum ether, lubricating oil, and turpentine.

Although not altered chemically or mechanically, the plastic is permeable in thin sections to certain organic acids, notably acetic acid and to some essential oils.

Absorption of water by polyethylene is extremely low. After one year at room temperature, the increase in weight due to absorbed water is only 0.15%.

When low-molecular-weight polyethylene is subjected to stress in the presence of certain types of polar liquids, it may undergo a phenomenon known as stress cracking or embrittlement (*2*). This cracking may occur in the presence of such liquids as alcohols, aldehydes, ketones, acids, esters, and surface-active agents, even though these compounds are poor solvents for, and are only slightly absorbed by, polyethylene. Vapors of volatile polar liquids may also cause this same effect, namely cracking. The probability of occurrence of environmental cracking decreases as the molecular weight of the polymer increases. Above a critical molecular weight polymers are no longer subject to embrittlement. It should also be emphasized that unstressed samples of polyethylene of any molecular weight remain free from stress cracking.

## Aging and Weathering

The chemical and physical properties of polyethylene remain substantially unchanged with age under indoor conditions. However, in the presence of ultraviolet light, as encountered outdoors, carbon-pigmented polymers are required to combat the tendencies for ultraviolet degradation. Carbon-pigmented polyethylene is used successfully over long periods of time under outdoor exposure.

Weather conditions, such as humidity changes or constant immersion in salt water or salt spray, do not affect the material in the least.

## Fabrication

The versatility of the hot-gas welding (*3*) method has been a major factor in the growth of polyethylene as a recognized construction material.

For chemical applications, fabrication by this method is by far the most important. Originally developed abroad, this technique has been further perfected in the United States to the point that weld-strength values of 90% are now standard

Fig. 2. Heat-formed sections.

(*4*) with polyethylene. In contrast, much lower weld-strength values are obtained in the welding of other plastics. The principle of the hot-gas welding process for polyethylene is similar to that of oxyacetylene welding of metals. The open-gas flame which furnishes the welding heat in the latter process is substituted by a stream of heated inert gas (nitrogen, argon, etc.). Filler rod employed in this process is usually of identical composition to that of parent material. Various sizes and shapes of filler rod depending upon the particular construction are used. In view of the sharply defined melting point, polyethylene lends itself well to this versatile and reliable joining method. Therefore, the chemical engineer has at his disposal not only a material which is an

Fig. 3. Heavy moldings, 57-in. diam. by 5½ in. thick.

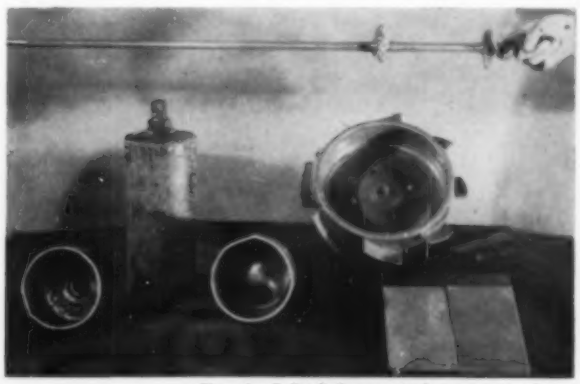


Fig. 4. Polyethylene-coated apparatus for chemical service.

excellent chemical barrier, but also one which is readily fabricated into shapes and structures limited only by his imagination.

Structural components for polyethylene fabrication include sheets, rods, pipe, and centrifugally cast tubing. Sheets are available in sizes up to 2 in. × 48 in. × 72 in. Rods can be obtained up to 10 in. in diam., and ducting and piping are available in diam. up to 27½ in. Of importance is seamless centrifugally cast tubing for ducting and piping (See Table 3). Wall thickneses up to 1½ in. are available for special applications.

Polyethylene is thermoplastic and can be shaped and formed by standard heat-forming techniques. Sheets are first heated to become soft and pliable and subsequently are draped or put between forms and cooled. This allows the construction of large cylindrical and conical-shaped pieces (See Figure 2).

**Table 3.—Seamless Centrifugally Cast Tubing Available in Structural Grade Polyethylene** (Agilene)

| O.D. | I.D. | lb./ft. |
|---|---|---|
| 2¾ | 2⅜ | .60 |
| 3 | 2⅝ | .69 |
| 3⅜ | 3¼ | .81 |
| 4 | 3⅝ | .91 |
| 4¾ | 4⅜ | 1.08 |
| 5⅜ | 5¼ | 1.28 |
| 5¾ | 5¼ | 1.73 |
| 6⅝ | 6⅛ | 2.00 |
| 8½ | 8 | 2.65 |
| 10¼ | 9¾ | 3.20 |
| 12½ | 12 | 3.85 |
| 14½ | 14 | 4.50 |
| 17½ | 17 | 5.75 |
| 20½ | 20 | 6.50 |
| 22 | 21½ | 7.00 |
| 27½ | 26¾ | 13.25 |

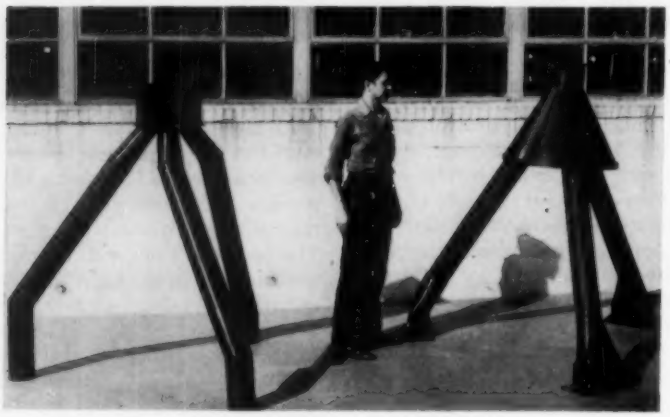


Fig. 7. Acid salt conveyor chutes.

Fig. 5. Lightness in weight of duct sections.

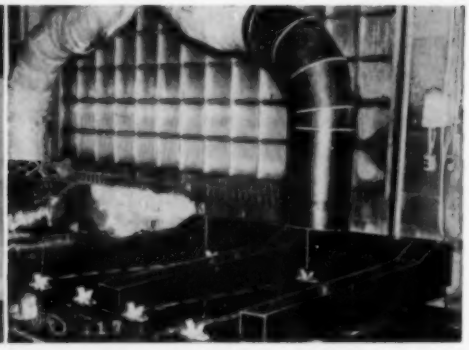


Fig. 6. Hydrochloric acid lateral exhaust hoods and ducting, 4 years life to date.

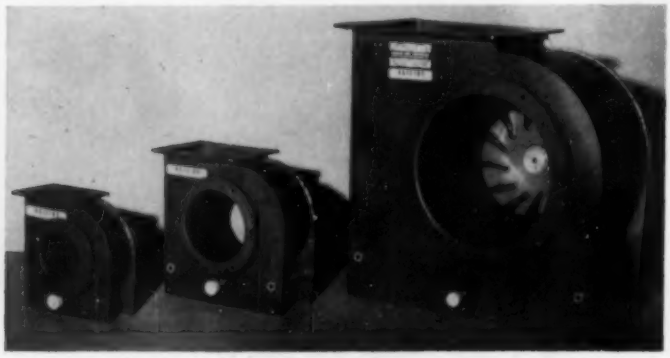


Fig. 8. Centrifugal fans.

Polyethylene is easily molded on standard machines. Because of its stability at molding temperatures, large and complex shapes are feasible. Recent equipment developments allow moldings up to 400 lb. for manufacture (See Figure 3).

Polyethylene pipe is extruded continuously up to 6 in. in diam. Smaller diameters are available in coils up to 400 ft. in length. Larger sizes are available in 20-ft. sections and thicker wall sections when centrifugal casting is employed.

Flame spraying of polyethylene is used for coating metallic parts where the combined properties of high impact strength and maximum corrosion resistance are desired. Coatings up to 3/32 in. in thickness are deposited in this manner.

In addition, polyethylene is floc-coated for large-scale production coating of metallic objects (See Figure 4).

Vessel linings are generally welded from sheet material.

## Applications

Ducting fabricated from seamless cast tubing has smooth inside surfaces and low frictional values. This minimizes fan power requirements for complex exhaust systems.

The light weight of polyethylene (⅛ the weight of steel) is an advantage in reducing installation costs for ducting (Figure 5). Its impact strength eliminates breakage problems encountered with other plastic materials. Polyethylene exhaust ducts are particularly applicable in the metal cleaning and finishing fields. Figure 6 shows a polyethylene exhaust stack for 20% hydrochloric-acid fumes. This installation has been in service for almost 4 years with no signs of corrosion.

Ducting can be safely used at temperatures as high as 175° F. In certain cases ducting can be used at temperatures as high as 195° F. with high gas velocities.

Polyethylene conveyor chutes for corrosive chemicals take full advantage of the nonsticking properties of the material. When fabricated in relatively thin wall sections, such chutes can be readily flexed to remove agglomerates (Figure 7).

A vital part of any completely corrosion-resistant duct system is the centrifugal fan, which is constructed of polyethylene (Figure 8). Blowers having capacities up to 15,000 cu.ft./min. have been fabricated. Large volume fans generally employ welded rotors. In smaller sizes one-piece molded rotors are now being employed. These fans have definite advantages over coated metallic fans. There is no problem of coating failure or crevice corrosion. The impact strength of polyethylene allows rugged fan performance since the blades cannot be chipped or cracked by solid particles which are accidentally conveyed into the fan blades.

Ducting systems are produced usually in prefabricated sections, ranging in length from 6 to 20 ft. as shown in Figures 9, 10, 11. These sections are connected either by flanging or through the use of tight-fitting, deep-friction collars.

Self-supporting polyethylene tanks have been fabricated in capacities up to 2,000 gal. (Figure 12). Such structures offer corrosion resistance on all surfaces. Painting or other corrosion maintenance is not required. For larger tanks metal reinforcement is used in the form of flame-sprayed structural members. Tank liners are fabricated from sheet material and mechanically fastened to larger tanks with studs or rivets.

Containers of various sizes and shapes are produced by hot-gas welding of structural components. Such containers have a weight advantage over other materials. In comparable sizes they are about one third the weight of glass and one thirteenth the weight of lead. Fabricated safety jugs and bottle carriers take full advantage of the nonbreakability and corrosion resistance of polyethylene.

The textile industry utilizes polyethylene for the storage and handling of bleaches.

The low values of taste, odor, and toxicity adapt polyethylene for piping and tankage in the beverage industries.

Paper treatment vessels are inert to various liquors and chloride bleaches at temperatures as high as 175° F.

Polyethylene dipping baskets are readily produced for the handling of metal parts in cleaning operations (Figure 13).

Polyethylene exhibits resistance to solutions used in photographic treatment and is employed in the construction of large developing, washing, and treatment tanks (See Figure 14).

Polyethylene pipe is usually joined with welded flanges or insert-type fittings. Flanged piping is preferable and fittings with attached flanges are available. Gaskets are not necessary except for high pressures, and for high-pressure applications metallic back-up flanges are recommended. Flanged joints permit connection to existing lines of other construction materials.

Globe-type valves (Figure 15) are fitted with a polyethylene-polyisobutylene sealing ring for leakproofness. Since polyethylene is not notch sensitive, square threads are

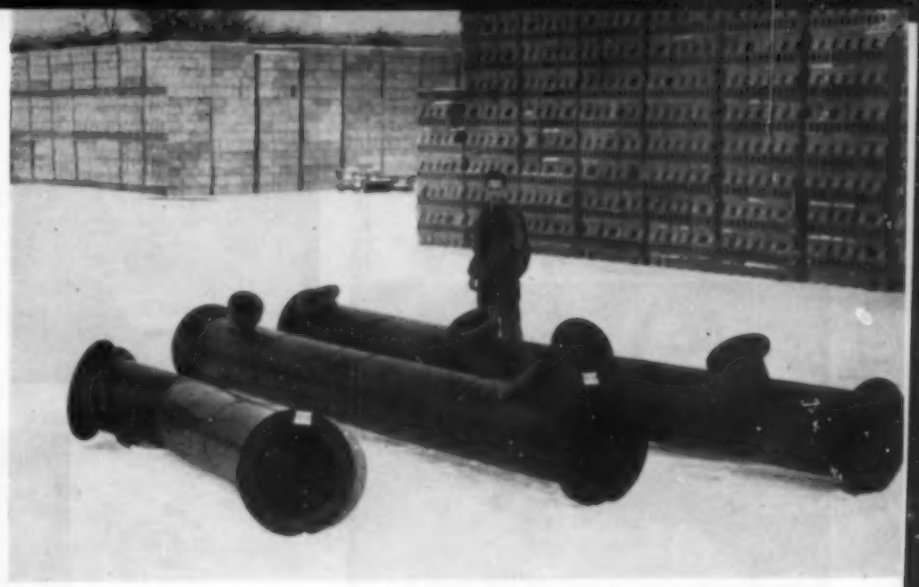


Fig. 9 ▲ and 10 ▽. Two views of prefabricated installation lengths of ducting.

Fig. 11. Weather cap.

Fig. 13. Dipping baskets for pickling operation.

Fig. 12. Self-supporting tanks for handling distilled water.

Fig. 15. Globe valve.

Fig. 14. Photographic development tank.

Fig. 16. Large molded hemispheres, 1-in. thick wall, 390-lb. weight.

machined into valve parts without danger of fragility.

Since it is unaffected by mercury which has long been detrimental to lead systems, polyethylene drainage plumbing for chemical laboratories is popular, and molded polyethylene sink-trap units are practical.

One-piece molded tanks up to 100-gal. capacity have recently become available to the chemical industry. Large moldings in polyethylene are used frequently in nuclear engineering for shielding and electrical characteristics. The ease of decontamination and low-temperature properties make polyethylene ideal for such uses.

Diffusional equipment in polyethylene includes absorption and scrubbing towers fitted with packing of the same material. In tower packing, the lightness and nonbreakability of polyethylene are important.

## The Future

One-piece construction of large vessels and structures in polyethylene appears quite promising as techniques in molding constantly improve. Moldings of surprising size, such as hollow polyethylene spheres, have been produced. The vessel shown in Figure 16 is 53-in. diam. and has a wall thickness of 1 in. The total weight of the entire sphere is 390 lb. The actual moldings are hemispheres which are welded together to produce the final unit.

The irradiation of polyethylene promises a material which will have unique properties desirable in many applications. Such irradiation is remarkably similar to the vulcanization of rubber. Polyethylene is changed from an easily fusible thermoplasic to a thermosetting material which retains form stability at temperatures as high as 400° F. Certain mechanical properties are improved and these improvements are retained at elevated temperatures. Solvent and chemical resistance are increased and the annoying phenomenon of stress cracking is eliminated. Yet, within proper dose ranges, irradiated polyethylene retains all the traditional properties of conventional polyethylene: toughness, flexibility, impact resistance, and complete inertness in most chemical environments. Application for this material will include such items as heat-resistant tanks which have to be continually or frequently sterilized at boiling-water temperatures, electrical insulators for higher temperature utilization, and liners for chemical tanks which must withstand higher temperatures and be completely free from stress cracking.

## Conclusion

Polyethylene fabrications offer a satisfactory and long-lasting solution to many of the particularly annoying corrosion problems of today. Its utilization in the field of chemical engineering will be even greater as more process engineers become acquainted with the unique adaptability of this material to their particular needs.

### Acknowledgments

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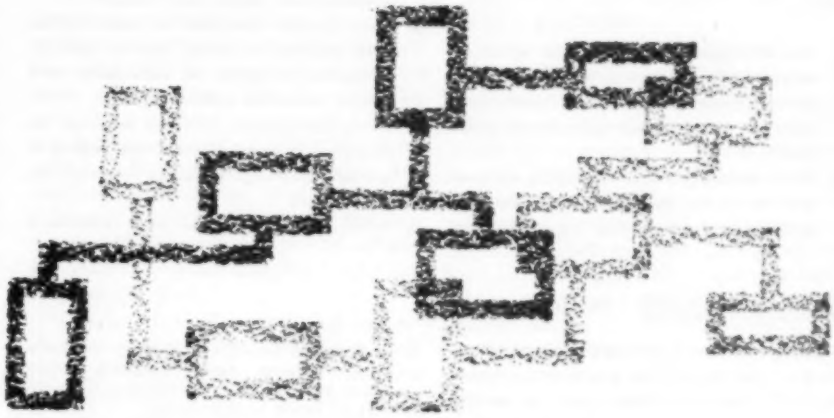


# HOW'S YOUR ORGANIZATION?

*Lounsbury Fish* | Standard-Vacuum Oil Company, New York

Organization is the means through which management divides, distributes, and balances the total management load; it is the mechanism through which management guides, coordinates, and controls the business. The proper design of that mechanism in relation to the needs and objectives of the business has a profound bearing upon the effectiveness and productivity of the total management effort.

For many years industry has spent millions on improving and tooling up its productive facilities, but only recently has it begun to realize the importance of making sure the management mechanism is best designed to do the job.

Developing a sound organization plan for an enterprise is, essentially, an engineering or architectural type of job—designing the structure and mechanism of management so that those who have the management responsibility can most easily and efficiently achieve their objectives. Engineers will detect in this proceeding an important application of the engineering method—the orderly, logical, planned approach to the problem of management.

What are the objectives, the tests, the main things one has to consider in designing a sound organization plan for a business, or in appraising the adequacy of an existing company plan?

First we must know where we are trying to go! We should have clearly in mind the long-range plans and objectives for the business as a whole. Developing an effective management organization is a long-range undertaking and one must look well to the future in laying the foundations.

As we all know, if there is a vital job to be done, or we are interested in making maximum progress in a given field, there is no substitute for putting a fully qualified man in charge with nothing to do but do that job well — determining the needs and opportunities, formulating plans, and driving through to accomplishment.

In the same way it is tremendously important in designing the organization structure for a business, to provide primary concentration of management attention upon the major needs, objectives, and opportunities of that business.

Turning next to the more specific requirements of a well-designed, company organizational plan, how can the chief executive and his associates make sure that their organizational house is in first-class order — that the subdivision distribution, and relationship of management responsibilities are best adapted to the needs of the business?



which it is practical to exercise at that

I believe they might profitably pursue the following lines of inquiry, in some depth:

1. Can the business as a whole be advantageously subdivided into more easily and effectively manageable "little businesses," each relatively complete and self-sufficient within itself?
2. Is the operating structure efficiently designed from the bottom up, to secure optimum delegation and distribution of the management load; logical, clear-cut fields of responsibility; maximum, feasible jurisdictions; and minimum levels, layers, and linkage?
3. Have essential functional or staff services been provided in proper balance and coordination in support of each center and level of operating responsibility?
4. Is top management effectively organized to discharge its responsibilities with respect to over-all planning, guidance, coordination, and control?
5. Finally, do all responsible individuals throughout the company have logical, well-rounded fields of responsibility, clearly defined and well understood?

If a searching appraisal provides a satisfying answer to each of these main aspects of the company organization plan, it may safely be assumed that the management is well mounted to do the job. To attain fully each of these primary organizational objectives, however, takes a lot of doing.

## The Subbusinesses

The first aim — where the size and nature of the operations warrant — should be to divide the business as a whole into components which are in themselves relatively complete and self-sufficient subbusinesses, each with full profit-making responsibility. This usually means that they must have an essential degree of responsibility or control over the primary factors which determine profitability, particularly, the determination of *product line, manufacturing,* and *marketing.* In addition, the component businesses should, as far as possible, be *big enough* to justify a potent management team; *small enough* for that team to "get its arms around"—to know the business and its problems, its people, its industry, its competition, its opportunities—to be "on top of the job"; *separable,* complete, and homogeneous as to field of opportunity, essential elements, and physical facilities, including all highly interdependent operations; and responsible, accountable, and *measurable* as to results achieved on a "profit-earned-on-capital-employed" basis.

Where the nature of the business permits, this form of subdivision into semi-autonomous smaller businesses has certain *advantages*:

1. It permits the widest delegation and decentralization of management initiative, responsibility, and authority.
2. Components which thus qualify as complete subbusinesses can safely be given wide latitude in making their own management decisions—in "running their own businesses."
3. It provides fullest opportunity for business initiative, resourcefulness, enterprise, and "drive," multiplying the centers of profit responsibility.
4. The members of each component management can most readily see the needs, consequences, and costs of alternative courses of action in terms of that all-important measure—effect upon profit.
5. Each component business has, within itself, the means of coordinating and controlling many or most of its own business problems, without burdening the "high command."
6. It therefore provides widest opportunity for self-determination, self-guidance, self-coordination, and self-control, in lieu of heavy dependence upon central management.

Thus, a large business which can be subdivided on this basis can enjoy the benefits of management simplicity, potency, and maneuverability which we normally associate with ably managed smaller businesses, and, at the same time, derive the benefits of combined resources of money, research, "know-how," diversification, and integration in helping the component businesses to do an even better job of rendering service and value to the public than they could do alone.

The chemical companies and many manufacturing industries have made widespread use of this form of organization—usually through the creation of relatively autonomous *product divisions.* The oil industry, on the other hand, finds it difficult to subdivide on a product basis since all the products usually come from the same barrel of crude in a common plant. In many cases, however, a satisfactory breakdown into relatively independent subbusinesses has been achieved on a regional basis, as where separate companies are formed to do business in different countries.

Where subdivision of the entire enterprise into true subenterprises is not feasible (and for the further subdivision of operating responsibilities within the subenterprises), it is necessary to resort to a *functional breakdown* into operating departments or divisions such as manufacturing and marketing. For companies of limited size this form of organization can be quite effective, with a high degree of specialized knowledge and direct responsibility within each functional field. As applied to large enterprises, however, a functional breakdown has the distinct disadvantage that single functions are usually *dependent parts* of the business as a whole, and it is necessary to bring a high proportion of the management problems through functional channels to the very top (frequently the President's office or the Board) in order that they may be properly coordinated with other related aspects and an intelligent decision reached, in the over-all interest. This tends to overload topside management. Further, it tends to limit the experience of rising executives to their respective fields of functional specialization, and restricts the development and functioning of well-rounded executives concerned with the over-all profit-making responsibilities of general management.

## The Operating Structure(s)

With the business as a whole broken down into logical, separable subenterprises to the extent that this is practicable, it is in order to consider the further breakdown of the operating organization along functional lines. Here again, there are a number of important objectives to be kept in mind:

1. Each operating subdivision at any level should comprise a *completely functional, physical, or geographical entity,* the elements of which are compatible and related, and "belong together."
2. Each should represent a *clear-cut field of responsibility,* the scope and jurisdiction of which can be clearly bounded and defined and for which a competent executive or supervisor can be held squarely accountable, on a measurable basis for results, for costs, and for exercising good business judgment.
3. Each, in ascending order, should represent the *widest jurisdiction,* with the maximum number of subordinate elements or people—which the executive or supervisor-in-charge can effectively supervise—depending upon the extent of their need for attention, review, guidance, coordination, and decision, from his office, as well as upon geographical factors.
4. Each, in ascending order, should be designed to be as *self-sufficient* as possible, with the fullest measure of responsibility and authority

**which it is practical to exercise at that level, thus minimizing the burdens of management at higher levels and placing local management in position to be most effective in dealing with local problems, employees, customers, competitors, and governmental authorities.**

5. **Each should have a clear-cut, workable basis of *relationship* with other elements of the organization with which it must deal.**

While these may appear to be simple and obvious guides to sound organizational design, it is surprising how often they are violated, resulting in heavy, though undisclosed, penalties in excessive administrative overhead, multiple handling, and red tape. On the other hand, effective application of these principles can have far-reaching benefits in assuring a sound basis for optimum *delegation* and *distribution* of the management load; in eliminating unnecessary management *levels, layers,* and *linkage*; in minimizing the number of *management positions*, supporting elements, and costs; in increasing *management effectiveness* through greater clarity of purpose, promptness, and directness of action, and shorter lines of communications; and maximizing the interest, challenge, and worth of each *responsible job.*

### The Operating Managers

With the business thus efficiently broken down into its logical, separable, operating divisions and subdivisions, our next concern is that each of these components have an adequate management organization that is responsible, accountable, and able to do full justice to its management needs.

Responsibility for conducting the affairs of each of these operating components should be centered and personalized in a single competent executive or supervisor. From the chief executive at the top to the foreman at the base level of management, these men-in-charge constitute the *line organization.* They are the links in the chain of command. Each is the boss, the head man within his field, and should have a primary title in recognition thereof. Each should stand squarely accountable for the over-all success of his operations, for his contribution to profit or loss, for his costs, and for the burdens he imposes on service departments. Each has an over-all job of management to do; he is a *generalist* rather than a *specialist*; he has the full range of management obligations: he must worry about planning, organizing, guiding, coordinating, and controlling; about personnel, training, motivation, and morale; about facilities, operations, maintenance, and costs; and about employee and public relations.

### The Functional Staff Services

Faced with this wide range of important responsibilities and the urgencies of operating coordination and decision, the line members of management seldom have enough time for thoroughgoing analysis of complex problems, for studying basic needs and sweating out sound solutions, for thinking up new ideas, and working out improved methods, and for following and evaluating new developments and opportunities in the art and the industry. They are too busy "getting out the wash."

This is where the functional or *specialized staff services* come in. Their job is to facilitate the work of the line organization. They are the means through which each line executive or supervisor secures the necessary assistance, specialized knowledge, and concentrated attention upon the different aspects of his responsibilities which will permit him to do a fully effective, well-rounded management job. In effect, they constitute the "brain trust" upon which he relies to "make him look smart" as a manager. How smart he is able to look depends upon their caliber, authoritative knowledge, and effective utilization.

Broadly speaking, each staff element is responsible for *assisting* the executive office to which it is attached, as well as all subordinate members of operating management, in determining the basic *needs* within its specialized field; in formulating *plans, programs, policies,* and *recommendations* for meeting these needs; in securing necessary *approvals* and *authorizations*; in enlisting necessary *understanding, acceptance, cooperation, and support*; in *advising* and *assisting* executives concerned in overcoming difficulties—in reaching desired objectives; and in *following, appraising,* and *reporting* upon over-all progress and results.

The staff organization must achieve these results without direct authority—through selling, persuading, advising, guiding, assisting, serving, appraising, and recommending—aided by the interest and support of the executive served. They must rely upon the authority of the facts, well marshaled and presented; the expertness and soundness of their judgment and advice; and their tact and persuasiveness in dealing with the line organization—rather than upon the power of command—in accomplishing these purposes.

Since the justification for staff is to assure a more effective and better balanced management performance than the line organization could achieve unaided, its caliber and quality are of top importance. A poor staff may be a liability, whereas a higher-powered group of experts in the same situation may prove to be a gold mine.

With these general considerations in mind, our first concern is with the organization of the *general staff services.* They have a twofold job to do: (1) to assist *top executives* in studying over-all needs, problems, and opportunities; in formulating objectives, plans and policies; and in appraising programs, progress, and performance throughout the company, within their respective fields of specialization; and (2) to furnish expert advice, functional guidance, and common services to *operating management* (and other staff elements), at all levels, as necessary to assist them in doing the best possible job.

In addition to the general staff services, one must also consider the needs of individual operating components for their own staff experts as members of their own management teams. This raises the question as to the most advantageous balance and disposition of staff resources between the different levels. Among the factors which need to be taken into account in this connection are the following: The central staff is

**management**

obviously in the best position to supply specialized assistance, based upon a coordinated knowledge of general policies and objectives and best practice throughout the company and perhaps the industry. Because of the extent of the need, the size of the stakes, and the importance of the problems in each specialized field, on a company-wide basis, the central staff can usually justify a more complete and potent team of experts than could any one of the operating components. Furthermore, concentration of functional staff services at the general management level provides the widest field of usefulness, assures breadth of view and objectivity in the company's over-all interest, and minimizes duplication of specialized personnel among the operating components. On the other hand, essential staff services built into the respective operating managements tend to be more conveniently available, more conversant with divisional needs and problems, more acceptable (if less influential) as "members of the family," and promote the objectives of decentralization and self-sufficiency.

In resolving this problem, one must, of course, take into account the needs of the particular company, considering

its size, geographical extent, and nature of primary components. In small companies staff resources are usually centralized in the interests of economy and efficiency. In larger enterprises—particularly in those which are comprised of a group of product or regional subbusinesses—in addition to the general staff services, there is usually some staff representation at the divisional level.

In this latter connection, one of the interesting problems which the larger oil and chemical companies have had to face is to determine what part of the research, engineering, and technical service staff should be set up as a general service facility, and what part should be built into the product division organizations where it can give undivided attention to divisional needs and problems and, as a "partner in the business," contribute directly to its success.

Regardless of other considerations, however, two overriding principles should be kept in mind in designing the functional staff organization: (1) each member of the line organization, from the chief executive to the foreman, should be able to secure from some convenient source the specialized advice, assistance, and service he needs in order to do a fully effective, well-balanced management job; and (2) the staff elements in each specialized field throughout the company should work in *close functional coordination*, under the guidance of the general staff executive in that field, as a potent aid to top management in assuring coordination of thinking, understanding, and effort toward common objectives in the over-all interest.

## Topside Organization

Having thus taken steps to make sure that the operating responsibilities are divided and grouped into the most effectively manageable components and that these components have the management tools they need to do a first-class job, our final concern is with the organization of general, or over-all, or top management.

Top management has the awesome task of looking down the road, weighing the different fields of opportunity, assessing basic strengths and weaknesses, appraising and forecasting the trend and impact of technological, competitive, economic, social, and political forces and developments, and in this light, plotting the most strategic and fruitful future course for the business—its basic objectives, its guiding policies, its most auspicious directions, dimensions, and locations.

The problems within this field are among the toughest with which management has to deal. They are profound and abstruse, and require a great deal of heavy thinking. Unlike the more tangible problems of operation, they seldom have visible deadlines or due dates and so too often are put off for the "rainy day" that never comes, until the inexorable tide of events catches the company at a disadvantage.

In too many businesses the principal members of management are so heavily engrossed and preoccupied with the compelling problems of current operation that they are not able to give adequate time and attention to these broader problems that lie in the realm of industrial statesmanship. Yet these are the problems, whether they are so recognized or not, to which sound and farsighted solutions are of utmost importance in determining the ultimate destinies of the business.

As a company grows in size and complexity, it soon reaches a point where one man—the chief executive—even with competent advice cannot do full justice to this vital need. At this point consideration needs to be given to elaborating the chief executive into a team—a balanced group of carefully selected individuals, usually officers or directors, at the policy level—who have the time, the objectivity, the range of experience, the breadth of vision, and the freedom from operating involvement which will permit them to share with the chief executive the over-all responsibility for charting a sound and strategic long-range course for the business as a whole; for providing over-all leadership, guidance, and coordination in reaching the established objectives; and for sitting in final judgment on major management plans, proposals, performance, and personnel.

The selection and functioning of such a potent, balanced group above the "operating level" can have a very considerable influence upon the ultimate success and "gate receipts" of the enterprise.

IN CONCLUSION, we might say that a well-designed organization plan is built around the natural divisions and subdivisions of the total management job. It clarifies and maximizes individual responsibilities, permitting each member of the management team—line or staff—to concentrate his full energies upon the achievement of vital management purposes, without the personal frustrations and economic penalties which all too frequently result from faulty balance in the management structure and loading; from illogical assignments and jurisdictions; from confusion, diffusion, and multilayering of responsibility, duplication of effort, and administrative red tape. Thus, a sound plan can be a most effective factor in stimulating and guiding total management effort toward achievement of company objectives, with great advantage to all concerned.

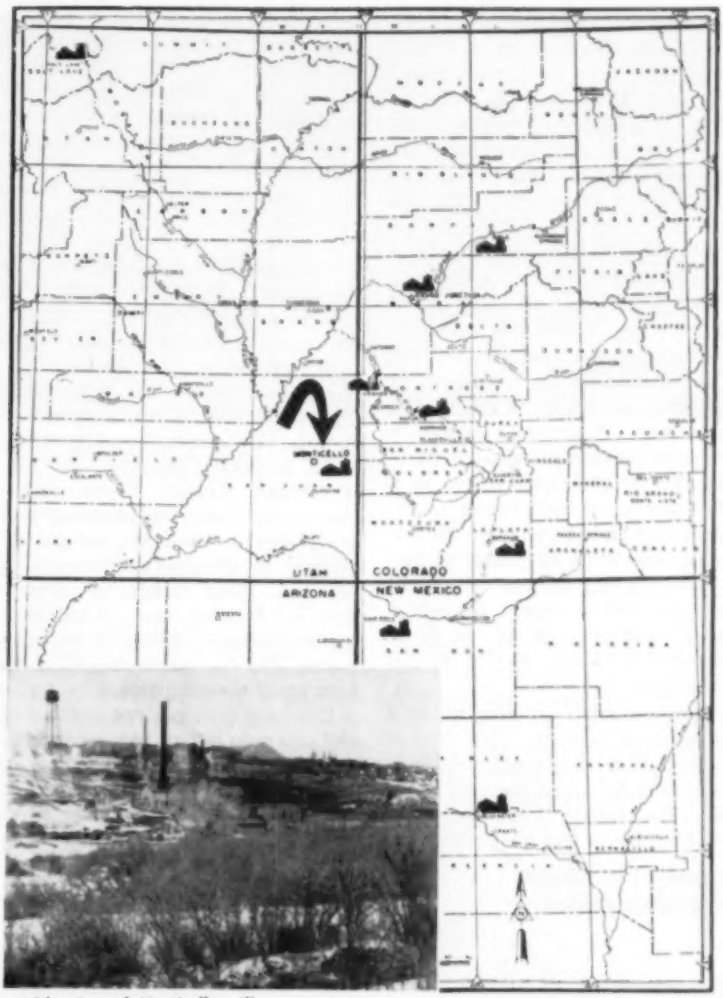
The modernization and streamlining of a large organization to fit best its needs and opportunities cannot, however, be accomplished in a day; it is a long-range job which usually requires redesign of the structure, remolding of long-established traditions and habits of thought, and gradual reassignment and regrouping of personnel, as it becomes opportune to make needed changes.

Because of the close interdependence and relationship between the parts of an organization and the importance of consistency in treatment of the various elements, the job should be approached from an over-all standpoint and should be considered in the light of the entire scope of the company's operations. *It is impossible to design properly a part unless one knows what it is to be part of!*

Finally, I would like to suggest that a good executive is like a good general in the following ways:

1. He makes effective use of his *intelligence service* to sound out the enemy's (or competitor's) strengths and weaknesses, to study the changing odds and opportunities of the business.
2. He determines his objectives, *plans his campaign* to reach them, and weighs the costs and logistics of production and distribution.
3. He *deploys his forces* most strategically for the assault upon his objectives, in sufficient concentration to do the job without wasting resources.
4. He makes sure that every man, from the bottom to the top, is properly *trained* to do the job—that he knows what to do and how to do it.
5. He arranges for *artillery* and *air support* (specialized functional services) to aid his ground forces in reaching the objectives.
6. He makes sure of his *supply lines* (raw materials, supplies, or products).
7. He himself provides the *leadership, guidance,* and *coordination* so essential to the success of the whole campaign.

*Presented at A.I.Ch.E. 47th annual meeting, New York.*




Location of the uranium mills in the Colorado plateau area . . . 1954



outside view of Monticello mill

# MAKING uranium AT MONTICELLO

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The Monticello mill, located at Monticello, Utah, is one of nine uranium mills in operation on the Colorado Plateau at the present time. The others are located at Rifle, Uravan, Grand Junction, Durango, and Naturita, in Colorado; Salt Lake City, Utah; and Bluewater, and Shiprock, New Mexico. A tenth mill is under construction at Edgemont, South Dakota, and is scheduled for completion early in 1956. Since this is an ever expanding field, milling facilities at Moab, Utah, are being planned to handle the Big Indian District ores, and further expansion will undoubtedly occur as new ore bodies are being found regularly in this 107,000 square-mile area. As shown on the map this region comprises parts of Colorado, Utah, Arizona, and New Mexico. Uranium is also being found in quantities that may well justify additional milling facilities in several other western states.

During World War II the vanadium mills in operation on the Plateau incorporated uranium flowsheets, and new mills were built to recover both uranium and vanadium.

After a period of inactivity between 1946 and 1948, the old wartime mills, including the Monticello mill, were reactivated and have been in constant and expanding production ever since. All mills on the Colorado Plateau, with the exception of Monticello, are owned and operated by private industry. The Monticello mill is owned by the government and, since its reactivation in 1948, has been operated under contract by the Galigher Company of Salt Lake City.

Although the mills recover in most cases two elements, uranium and vanadium, these two elements occur in nature on the Plateau in twenty-seven different types of ore, hence many modifications in flowsheets are necessary in order to treat all these variations. Therefore, in discussing the processing controls at Monticello, an examination of the flowsheet is also necessary.

Operations at the Monticello mill are shown in the pictorial flowsheet and consist essentially of the following:

- weighing, sampling, and stockpiling of the ore.
- crushing (with drying if necessary) to −10 mesh.
- salt roasting at 825-840° C. for 55-min. retention time.
- quenching of the calcine with a hot $Na_2CO_3$—$NaHCO_3$ solution.
- grinding to 60%-100 mesh.
- agitation followed by CCD washing with the pregnant liquors being clarified and sent to precipitation.
- precipitation of the uranium as a sodium uranyl vanadate which is filtered off and refined by a fusion and water leach.
- vanadium precipitation from the uranium precipitation filtrate.
- vanadium refining by washing and fusing.

Many different types of ores are received by truck from several tributary mining districts. The major types are: carnotite ores from the Slick Rock Dis-

trict of Colorado; copper-uranium ores from the White Canyon area of Utah; Shinerump-type ores from the Inter-River District, Utah; and up until recently the uraninites and tyuyamanites from the mines of the Utex Exploration Company located in the Big Indian Wash country to the north of Monticello.

The procedure used in receiving these shipments from the mines is as follows:

The ore trucks are weighed in on large truck scales, then dumped on concrete receiving pads. Before the load is dumped, a wooden stake is placed on the pad with the shipper's name and date of receipt. A moisture sample is taken by grab sampling several parts of the pile, the sample being placed in a container having a tight-fitting cover. A stake is also placed on top of the pile and subsequent loads are dumped end-to-end from the original load and noted on the stake until a shipper declares a lot closed. The average size lot is 63 tons but lots have run from 5 to 200 tons in weight.

The moisture sample is weighed on a Toledo moisture balance. This type of scale is used since it is rapid and eliminates any calculations on the part of the sampler. The sample is mixed quickly on a bucking board and weighed on the moisture balance. This balance is calibrated to read from 0 to 30% moisture. The sample is then dried at 110° C. in a small drying oven for at least 16 hr. It is then reweighed and the moisture content read directly from the scale. The moisture content averages about 5%. This figure is then used to determine the dry weight of the entire lot.

Preparatory to sampling for metal content, an entire lot is picked up with the use of a 3-wheel mechanical loader such as a Hough loader and trucked to the coarse ore bin of the sampling unit. It is sampled in three stages with size reduction of the ore before each succeeding sample cut is made. Crushing is done in jaw crushers and sampling by Vezin automatic samplers. All the ore is crushed through 1½-in. size, and the rejects from the sampling process are placed in stockpiles designated according to the process amenability of the ore. Final sample preparation is done in a bucking room. After the ore is ground through 120-mesh, an approximately 2½ lb. sample is split down to four equal weight pulps.

One pulp is then given to the shipper; and one pulp is sent to a central laboratory at Grand Junction where pulps from all the ore-buying stations of the Commission are assayed for uranium, vanadium, and lime content and, in the case of copper-uranium ore, the copper content. In addition to uranium, the Commission pays for the vanadium content of the ores and part of the copper content, if present. No payment is made for any other metals and a deduction is usually made when ores contain more than 6% $CaCO_3$ to compensate for the added expense incurred in processing these "high-lime" ores. The ore-receiving and -sampling portion of the Monticello operation is handled under contract by the American Smelting and Refining Company. In addition to the Monticello location, this company operates for the Commission other strategically located buying stations throughout the Plateau and other ore-producing areas.

Based on amenability tests performed in the plant laboratory and at the U. S. Bureau of Mines in Salt Lake City, certain stockpiles or combination of stockpiles is scheduled for treatment. Amenability tests usually consist of a series of laboratory-scale experiments with the following procedures:

**Salt roasting at 850° C. followed by hot carbonate leaching; roasting the sample at 550° C. followed by hot carbonate leaching; salt roasting at 850° C. followed by acid leaching; and straight acid and carbonate leaching of —10 mesh material with no pretreatment. Filtration**

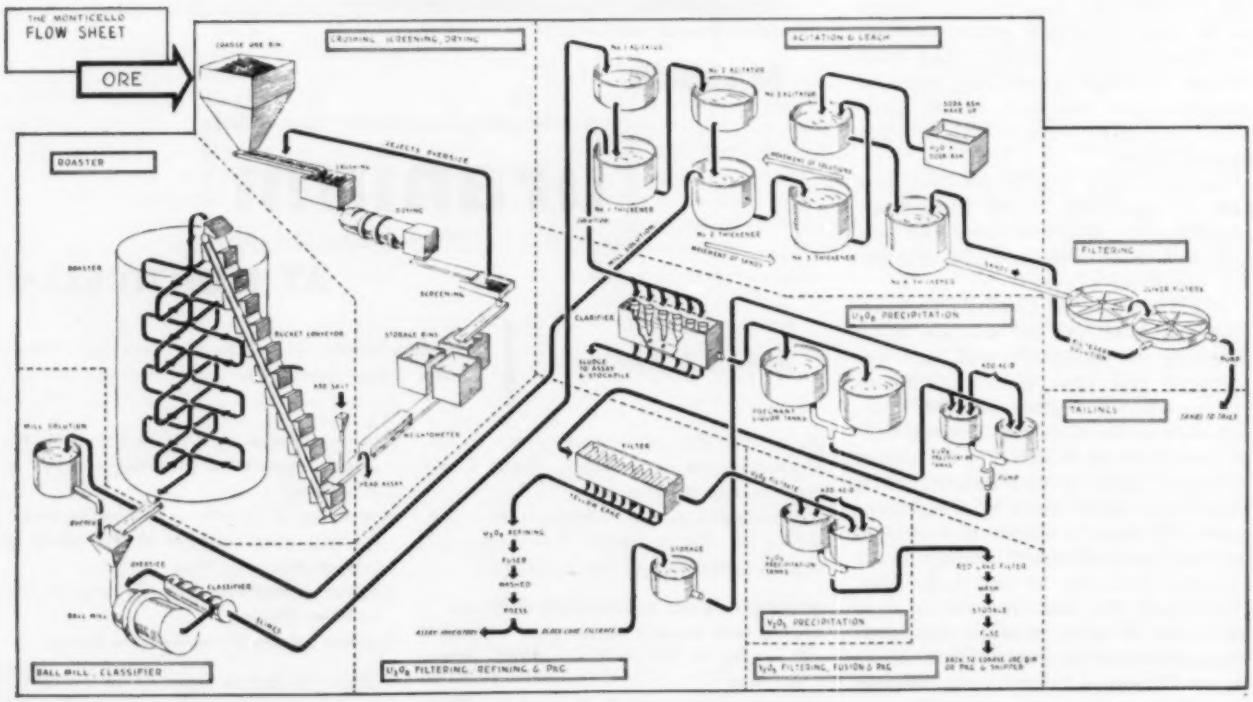


Fig. 1. Monticello, Utah, uranium processing mill: roaster discharge quenching system.

Fig. 2. Monticello, Utah, uranium processing mill: thickener room.

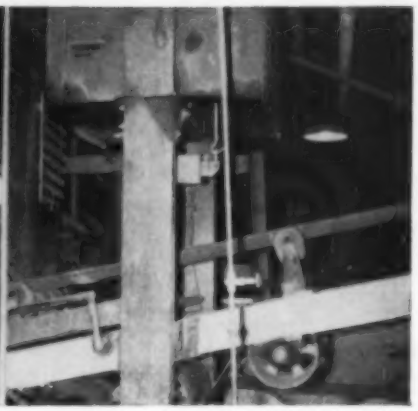


Fig. 3. Monticello, Utah, uranium processing mill: weightometer.

and settling tests are run on pulps for each procedure. Special tests are given ores that do not respond to any of the above treatments. A blend of seven parts normal carnotite ore to one part Temple Mountain carbon base ore was treated in the plant circuit for several months. This blend was made by placing a Hough loader scoopful of Temple Mountain ore on each truckload of carnotite ore delivered to the mill's coarse ore bin. In addition, an amount of fused vanadium was added to each truckload being dumped into the bin to produce a vanadium to uranium ratio of approximately 10 parts vanadium to one part uranium. Although different blends of ore were subsequently treated, the addition of fused vanadium has continued as test work has indicated that this ratio produces appreciably better uranium extractions in a salt roast than the 5:1 vanadium to uranium ratio found in the carnotite ores on the Plateau. It has been found at Monticello that even higher extractions could be had by going to a 15:1 vanadium to uranium ratio. However, serious handling problems occur at that ratio at Monticello although the ratio is chemically attractive.

The maintenance of the vanadium to uranium ratio becomes the first processing control in the mill. Although this ratio is necessarily based on the previous day's sample, fairly uniform ratios occur in stockpile, and experience has shown that a consistent 10:1 vanadium to uranium ratio usually is maintained.

The material from the coarse ore bin is fed by means of an apron feeder to a New Holland impact breaker where it is reduced to −10 mesh. If the ore is wet, it is dried in a rotary drier and then screened on a double-deck vibrating screen. All the ore or only a portion of the ore, depending on its moisture content, may by-pass the drier. The +10 mesh material is returned to the breaker for crushing. Since this is a relatively soft sandstone ore, the circulating load is rarely greater than 75%.

A rotoclone dust collector is provided with hoods and vents at all transfer points. This is advisable because not only does it eliminate dusting as an undesirable working condition, but uranium which tends to concentrate in the finer sizes can be recovered and returned to the circuit.

The −10 mesh ore is sent to the fine ore bins by means of a conveyor belt so arranged that the ore can be divided to flow to all three bins, or to only one bin, as may be desired. Ore is discharged from all three bins simultaneously in order to obtain a more uniform feed to the roaster. The discharge from the three ore bins is conveyed over a continuously recording Merrick weightometer to a bucket elevator which feeds the Skinner roaster. At the conveyor discharge a Geary-Jennings automatic sampler cuts the stream once every 13 min. The sample falls from the cutter down a flexible tube to a sealed container. This becomes the plant's head sample. In addition, an hourly hand sample is accumulated in a sealed container for moisture determination. Each sample is brought to the laboratory every 8-hr. shift. The moisture sample is processed as follows:

A split is made with the use of 1,000 g. from approximately 20 lb. collected. This is weighed, dried for 16 hr. at 110° C., and reweighed. A composite sample from the three shift head samples is made and assayed for $U_3O_8$, $V_2O_5$, and $CaCO_3$. The Geary-Jennings sampler is a relatively trouble-free device that needs little operating attention, but the operator on duty usually observes its performance and checks the timing cycle at least once during the shift. The weightometer, however, for our requirements, needs more frequent observation. The operator, once each hour, checks the speed of the known length of belt with a stop watch, scrapes off exactly a 1-ft. section and weighs this on a small platform scale in order to control



the feed rate to the roaster. Once a week the accuracy of the weightometer is thoroughly checked. This is done by diverting approximately 1 ton of ore from the end of the belt into tared barrels and weighing them on a platform scale. The weightometer, read before and after this diversion, is adjusted if out more than 2%; otherwise, a factor is calculated and applied to the recorded tonnage. The platform scale, used in this test, is in turn checked with standard weights. Another similar check has been employed wherein 5 tons of ore are diverted into a truck after reading the weightometer, the truck being weighed on the ore-buying station's truck scales.

A stream of salt roughly equal to 8% by weight of the ore is added also to the boot of the elevator feeding the roaster. However, the salt control is maintained by taking a sample of the calcined roaster product and titrating for residual chlorides.

Four times a shift the operator takes a 10-g. sample of calcine, adds 100 ml. of distilled water, mixes for 10 min., lets it settle, and pipettes a 1-ml. sample into a 250-ml. beaker. The sample is made neutral with sodium carbonate

with a check on the *p*H with litmus paper. Potassium chromate is added as an indicator and a 0.028 normal silver nitrate solution is used as a titrating solution, and with this strength 1 ml. of solution equals 1% residual chloride. The target is 2% residual chloride. This amount insures adequate salt to be present in the roast to solubilize the uranium and vanadium when quenched with sodium carbonate mill solution.

The roaster is an 8-hearth Skinner type. Heat is introduced on Nos. 6 and 8 hearths from two oil-fired heat chambers on each side of the roaster. The temperature on hearths Nos. 1, 4, 5, 6, 7, and 8 is recorded automatically by a potentiometer connected to thermocouples on each hearth. The temperature rises from 100° C. on No. 1 to 840° C. on No. 7 hearth.

The Monticello roaster has a residence time of approximately 55 min. at temperatures of 825-840° C. Actually, this temperature is a compromise between the temperature necessary for optimum uranium extractions and the temperature necessary for optimum vanadium extractions.

A recording ammeter records the operation of the roaster motor. Any increase in load usually indicates slagging on one of the hearths and this causes a drag of the roaster arms which could result in expensive maintenance. The mill foreman with a quick glance can tell if the roaster is operating properly and if required maintenance was performed as needed. For this reason, the employees call this device "the mechanical stool pigeon."

The calcined ore is quenched with hot 5% $Na_2CO_3$ mill solution. The calcine is then sluiced, screened, and pumped a short distance to a ball mill—classifier circuit where the calcine is ground to about 60%-100 mesh. The classifier overflow is maintained at 30% solids by weighing a sample of the overflow on a pulp density scale. This scale is a beam balance with a 1-l. flask suspended from one end. This weight is then compared to a chart which gives percent solids calculated from the specific gravity of the ore and of the solution.

The ground calcine then passes to an agitator where live steam is added and further leaching takes place. About 55-65% of the uranium and vanadium values are dissolved in the quench and another 20% in the No. 1 agitator. The agitated pulp goes to a thickener whose overflow is the uranium and vanadium pregnant solution. The thickener overflow is clarified by pumping through a sock filter and the clarified liquor is pumped to one of two pregnant liquor storage tanks.

The thickener underflow is pumped to a second agitator where the pulp is reheated to 90°C., as heat is necessary to get good extractions with the use of sodium carbonate solution as a leaching medium. The pulp then flows to a second thickener. The overflow from No. 2 thickener goes to mill solution storage and this solution is used to quench the roasted calcine. The underflow of No. 2 discharges to No. 3 thickener and finally a fourth thickener in a straight countercurrent decantation system. Soda ash make-up is added in a small agitator and introduced to the No. 3 thickener underflow. Generally, another agitator is introduced into the circuit between the 3 and 4 thickeners to reheat the pulp in an attempt to obtain the ultimate recovery out of the ore.

Control for the leach circuit is maintained by analyzing for $V_2O_5$ content the Nos. 3 and 4 thickener overflows, the mill solution, and the clarified pregnant liquor. The operator titrates a 10-ml. sample with a ferrous ammonium sulfate solution after first oxidizing the vanadium with 1 drop of potassium permanganate. The ferrous ammonium sulfate solution is of such strength as 1 ml. of titrating solution equals 1 g. $V_2O_5$/l. It is true that any excess $KMnO_4$ as well as the vanadium is titrated, but this assay is considered an adequate control and never differs from the laboratory assay by more than 1 g./l. $V_2O_5$. In addition, the mill solution and No. 3 thickener overflow are analyzed for total carbonate content. The target strength of soda ash for the quench is 5%. Again, it is the operator who determines how much new soda ash is needed. He titrates a 10-ml. sample with sulfuric acid and methyl orange indicator. The sulfuric acid is of such strength that 1 ml. = 1% carbonate. In addition to the control by the operator, a composite sample is titrated in the laboratory each day. This sample is titrated for sodium carbonate, sodium bicarbonate, and sodium hydroxide. Typical concentrations are 40-45 g./l. $Na_2CO_3$, and 8-10 g./l. $NaHCO_3$, and no more than 2 g./l. NaOH can be tolerated or else significant precipitation of the uranium will occur.

The underflow from the last thickener is sent to Oliver horizontal filters for washing and then discharged to the tailings. The tailings are not weighed but are sampled with a Geary-Jennings straight-line automatic sampler that wipes a full cross-section off the conveyor belt every 15 min. into a container. This sample is assayed for uranium oxide and vanadium pentoxide. Water-soluble uranium is determined, also, to check the washing efficiency of the filter. The tails are then repulped with waste liquor from the vanadium precipitation and pumped to the tailings pond.

The pregnant liquors are sent to precipitation. Measurement of these liquors

Fig. 4. Monticello, Utah, uranium processing mill: pregnant liquor clarifier tanks; clarifier socks in background.

Fig. 5. Monticello, Utah, uranium processing mill: impact breaker crushing unit.

Fig. 6. Monticello, Utah, uranium processing mill: horizontal filter.

Fig. 7. Monticello, Utah, uranium processing mill: disc filter.

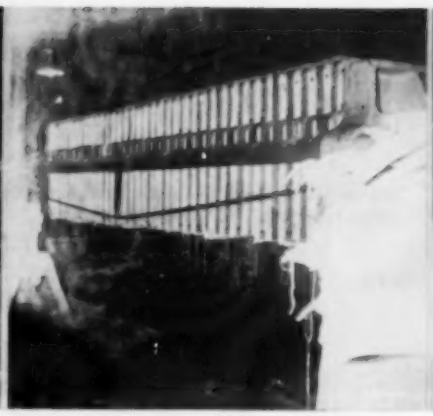


Fig. 8. Monticello, Utah, uranium processing mill: filter press.

Fig. 9. Monticello, Utah, uranium processing mill: precipitation tank room; vanadium tanks in foreground.

to the precipitate section was formerly done by flowmeters, but because of varying temperatures and concentrations, poor results were obtained. Now, pregnant liquor is drawn from one of two storage tanks. These storage tanks are equipped with sight gauges, and while one tank is being filled, the other tank can be discharged to precipitation. The operator draws the required amounts of pregnant liquor and acid by reading sight gauges on both tanks. Both the liquor and the acid are introduced to an agitator simultaneously and agitation begun. The operator determines the amount of acid necessary to precipitate a sodium uranyl vanadate, also known as artificial carnotite or "yellow cake," by titrating a sample of the pregnant liquor for total carbonate. From published tables the operator determines the amount of acid necessary. A second titration and acid adjustment is generally made. The *p*H is usually 6.0 at this point and is measured by hydrion paper comparison. The solution is heated to 80° C. and 25 lb. of sodium chlorate is added to insure complete oxidation. The slurry is brought to a boil and boiled for 30 min. This usually will be a sufficient time to precipitate the yellow cake.

The operator determines when the precipitation is complete by means of a fluorescent bead test. A sample of the boiling pulp is taken and filtered. Sodium fluoride powder and a drop of filtrate are fused on a platinum loop, cooled, and compared under a fluorescent light with other standard beads assaying 5 to 20 p.p.m. in 5 p.p.m. increments. The tank is dumped if the test shows below 10 p.p.m. $U_3O_8$. If the tank is dumped, the remaining portion of the filtrate sample is brought to the laboratory where the uranium is assayed by use of a fluorimeter. The fluorimeter has proved a valuable tool in uranium assaying of solutions. Rapid and inexpensive assays are its chief advantages. Accuracy on solutions of the grade being tested are well within tolerances. In most cases, however, the instrument is not sufficiently accurate to be used on ores or concentrates for anything other than obtaining approximate answers.

The yellow cake is filtered in wooden plate and frame presses. Since it contains about 75% moisture, it needs to be dried. Drying is performed by spreading the cake on the floor upon which is directed streams of hot air. This reduces the moisture content to about 25%. The cake is then sent to the refinery. The filtrate contains most of the vanadium; hence it is pumped to an agitator where further acid is added to a *p*H of 3.5. Sight gauges are again provided to measure the acid. Hydrion paper is again used to determine *p*H. Sodium chlorate is added and the pulp is brought to a boil. Recently ammonium sulfate has been added after the chlorate addition. The operator, again titrating a 10-ml. filtered sample with ferrous ammonium sulfate, determines when to filter the tank by a vanadium determination. The precipitation is complete if the filtrate assays less than 0.2 g. of $V_2O_5$/l.

The precipitate, a sodium metavanadate or "red cake," is filtered off in filter bottom tanks. The ammonium sulfate addition, before boiling, produces a high-grade precipitate. Two hot-water washes are necessary to make a specification grade product. This filtrate is used to repulp the tailing and the washed red cake is transferred from the filter to an adjoining bin by an ancient form of physical metallurgy—a laborer gets in and shovels out the tank. The red cake, containing 75-80% moisture, is fed to a fusion furnace and fused with excess air at 900° C. Moisture is driven off and a flake vanadium pentoxide is produced by dropping the hot vanadium pentoxide on a water-cooled steel belt. The flake $V_2O_5$ falls into tared 30-gal. drums for shipment. These are weighed out on a platform scale.

The refining of the yellow cake is done first by mixing it with salt, soda ash, and sawdust, and then fusing in a tilting pot reverberatory furnace at 900° C. These ingredients are measured roughly by the addition of shovelsful of each as required, and then the mixture is fed to the furnace by hand charging. The molten mass is poured into tared pans. It cools and solidifies quickly. It is weighed on a platform scale, then hand broken and fed to an agitator where it is given a water leach to remove the vanadium which became water soluble along with other impurities in the fusion step. A batch process is used; hence only enough fused material is added to form a filter press load.

The pulp is pumped from the agitator to a filter press. The first liquor coming off the press is known as "black liquor," and contains a considerable amount of vanadium and a small amount of uranium, so it is fed back to the yellow-cake precipitator to insure maximum recovery of uranium and vanadium. Subsequent liquors are used as washes for succeeding batches. When black liquor is added to the yellow-cake precipitation, more chlorate is needed and a longer boil is necessary in order to produce a uranium barren under 10 p.p.m. The filter cake in the press is washed with hot water and then blown with steam. The press is dumped and its contents placed in a steam-heated tray drier. After drying, the material is packaged in tared 30-gal. drums and weighed. It is pipe sampled and assayed for uranium and vanadium preparatory to shipment.

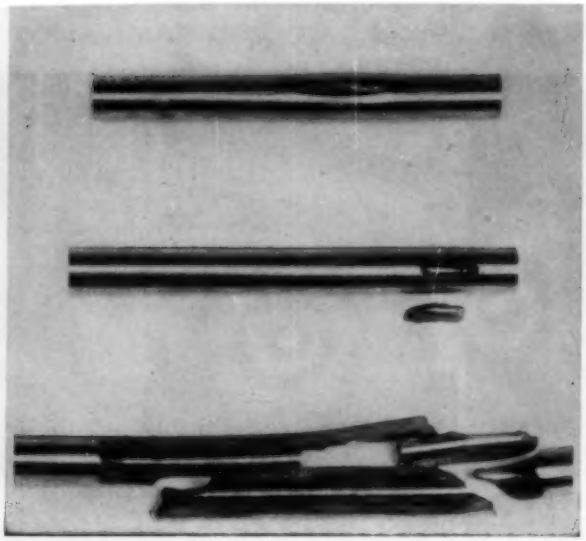


Since presentation of this paper, advances in technology and changes in the ore supply for the Monticello mill have dictated several modifications to the circuit, but the Galigher Company, with the methods outlined above, was able to keep close control of the Monticello flowsheet, to operate the mill with an extremely small loss of operating time and, equally important, to obtain good recoveries on the ores treated. Although several phases of the flowsheet described here will no longer be practiced at Monticello, certain other plants on the Plateau employ similar operations and procedures in the treatment of carnotite ores.

*Presented at A.I.Ch.E. Glenwood Springs meeting.*



Hydrogen attack of a metal is char-



Tubes ½" O.D. x ¼" I.D. x 6" long that were tested to destruction with hydrogen gas. *Courtesy Engineering Research Laboratory, Du Pont.*

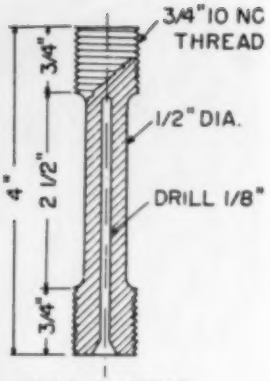



Fig. 1. Tensile-test specimen.

# EFFECTS OF HYDROGEN AT HIGH PRESSURES ON THE MECHANICAL PROPERTIES OF METALS

## I. Apparatus, Procedures, and Preliminary Results

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It has been known for many years that hydrogen-bearing gases at high pressures and temperatures can attack steels and other metals. Few data are available, however, on the conditions at which attack occurs, and almost nothing has been published about the effects of hydrogen alone at pressures above a few hundred atmospheres.

Metallurgists have long recognized the fact that hydrogen can diffuse into and be absorbed by steel even at room temperature, and from the first it was realized that such hydrogen absorption was in some way connected with a degree of embrittlement of the steel. The two sources of hydrogen which have usually been associated with this embrittlement are (1) environments with which the metal naturally comes in contact during the course of its manufacture and (2) nascent hydrogen liberated at the surface of the steel either by electrolysis or by chemical action.

In contrast to this, hydrogen absorbed from the high-pressure gas at room temperature has received scant mention in the literature, and a number of investigators who used hydrogen at pressures up to 4,000 atm. have made no mention of encountering any difficulty from hydrogen embrittlement at room temperature. The fact that room-temperature embrittlement by hydrogen from this source can be a serious problem became clear in the present work when several parts of the experimental equipment designed for high-temperature experiments at 4,000 atm. failed under a hydrogen pressure of about 3,000 atm. at room temperature. Experiments were then designed to investigate both the high-temperature effects and the room-temperature effects of high-pressure hydrogen.

During the course of the present work a warning appeared in the literature (*10*) on the dangers of using high-pressure hydrogen in steel equipment at room temperature. Mention was made of a series of bursting tests carried out on vessels under hydrogen pressure. As a control vessels were also burst under oil pressure. Results showed that in some cases vessels failed in a brittle fashion under hydrogen pressures as low as 2,000 atm., whereas with oil they were suitable for pressures above 7,000 atm. So far as is known these are the only tests which have been made heretofore for the express purpose of studying the room-temperature embrittlement of metals by high-pressure hydrogen, but they have not been reported in detail.

It would be well now to draw as sharp a distinction as possible between the terms hydrogen embrittlement and hydrogen attack. This distinction has not always been clearly drawn in the literature, but it would seem to be necessary. Hydrogen embrittlement of a metal is used here in a very restricted sense, and refers only to the decrease in ductility caused by hydrogen which occurs without the formation of any microscopically visible cracks or changes in microstructure or composition. The ductility of a metal so embrittled often can be almost entirely restored by heating at low pressure or even by room-temperature aging. If stresses are present in the metal, this embrittlement can lead to cracking, but this is to be regarded as a result of embrittlement rather than a part of it. Hydrogen embrittlement can occur with great rapidity. Apparently the very presence of hydrogen in the metal is the only requirement for embrittlement of materials which are subject to it. One widely held explanation for hydrogen embrittlement is that hydrogen atoms (dissociation of the molecular gas apparently occurs during adsorption on the surface of the metal) diffuse through the crystals of the metal and collect in the system of ultramicroscopic imperfections which is thought to exist within metal crystals. Here the hydrogen atoms recombine, and the relatively insoluble molecular gas builds up internal pressures which render the metal brittle. This embrittlement can, of course, occur at any temperature, but it is often masked at high temperatures by the effects of hydrogen attack. It is for this reason that the present experiments designed specifically for the study of embrittlement were carried out at room temperature.

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Hydrogen attack of a metal is characterized by a chemical reaction between hydrogen and the carbon in the metal to form methane, and the destructive effects of this action result both from decarburization and from internal pressures built up by the methane formed. This methane collects, over a period of time, primarily at the grain boundaries of the metal. The grains are eventually forced apart, and cracking, fissuring, and blistering result. These manifestations of hydrogen attack can usually be detected by microscopic examination. Naturally the metal is weakened and made brittle. Evidently the main differences in conditions required for hydrogen attack rather than or in addition to hydrogen embrittlement are that the temperature be high and that exposure be of relatively long duration. Since the rate of hydrogen attack is controlled by the rate of a chemical reaction, it is clear that both temperature and time are important variables.

The literature on the general subject of hydrogen in metals is voluminous; indeed Smith (*7*) lists 1,467 references covering many phenomena related to hydrogen embrittlement and attack as well as these subjects themselves. Such phases of the problem as adsorption, diffusion, solubility, permeability, etc., have been extensively treated in several books (*1, 7, 8, 11*).

Effects of ammonia-synthesis gas at high temperatures and pressures have been given considerable attention because of the commercial importance of the Haber process for making ammonia from its constituent elements. The most recent review of this subject is given by Ihrig (*2*). Ammonia-synthesis gas in its action on steel is considered to be more severe than hydrogen alone. All the manifestations of hydrogen attack may be present, and in addition, nitriding of the steel often occurs. However, steels attacked by ammonia-synthesis gas are probably also susceptible to attack by hydrogen alone.

Experimental and plant data on the high-temperature, high-pressure attack of gaseous hydrogen on steels and other metals have been reported by a number of investigators. The outstanding work is easily that of Naumann in Germany (*3, 4*). He investigated the effect of composition on the susceptibility of low-alloy steels to attack, and showed the value of additions of such elements as chromium, tungsten, titanium, and vanadium, which form stable carbides with the carbon in steel. Zapffe (*9*), Schuyten (*6*), and most recently Nelson (*5*) have published reviews of this subject, and have summarized the available results.

It was not the purpose of this preliminary investigation to obtain fundamental data on such problems as the permeability of metals to hydrogen gas or the solubility of hydrogen in metals. Neither were data sought to prove or disprove theories or to establish mechanisms of hydrogen diffusion into metals or of hydrogen attack or embrittlement of metals. Rather, the object was to ascertain what metals could safely be used with high-pressure hydrogen. Such practical results are of obvious value, and they must be available before comprehensive work of a more fundamental nature can be undertaken. Results must be regarded as preliminary, however, and not entirely conclusive, for our main efforts went into developing apparatus and procedures.

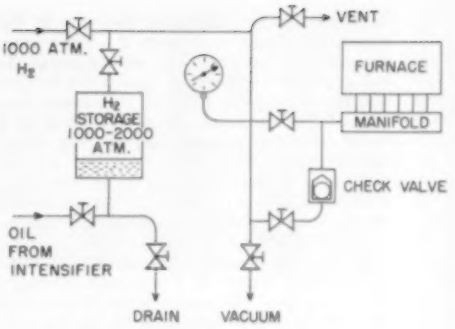


Fig. 2. Apparatus for high-temperature tests.

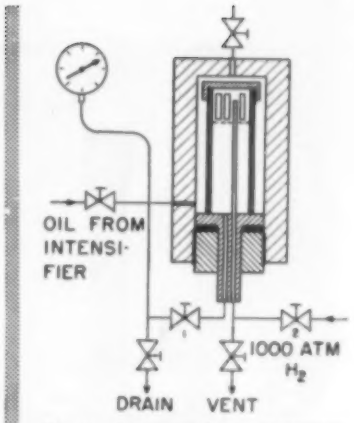


Fig. 3. Apparatus for room-temperature tests.

## Experimental Work

### HIGH-TEMPERATURE TESTS

In designing an apparatus for exposing metal samples to high-pressure, high-temperature hydrogen the following factors were considered as being of primary importance.

1. It was necessary to provide for the exposure of a rather large number of samples simultaneously; thus, the samples had to be relatively small.
2. It was desirable that the samples themselves be pressure vessels so that the usual stresses in such vessels would be developed.
3. The samples had to be of such a shape that a standard mechanical test could be made to determine the incidence and extent of attack.
4. Provision had to be made so that the bursting of a sample under pressure would be neither dangerous nor destructive.

In line with these requirements the samples were made in the form of standard, round tensile specimens with threaded ends as shown in Figure 1. This choice for the standard specimens resulted from the initial decision to use the results of tension tests as the criterion of hydrogen damage. These samples were relatively small, 4 in. in length, and they were made into pressure vessels having an outside to inside diameter ratio of 4:1 by drilling ⅛-in. holes along their axes from one end. A cone was machined at the open end of each hole to accept a length of high-pressure tubing through which hydrogen was admitted.

The tubing and samples were held together in sample holders, six samples to each holder. Each holder with its samples was placed in a separate electrically heated furnace. The six lengths of tubing from the six samples led to an external manifold as shown in Figure 2. For the sake of simplicity, only one furnace is shown, but there were actually five of them connected in parallel so that thirty samples could be exposed simultaneously. The five furnaces were each provided with a Powerstat variable transformer to control the temperature. The furnaces were made of 6-in. steel pipe, 2 ft. long, mounted horizontally. The sample holders were formed from steel bars about 22 in. long, 1 in. wide, and 1½ in. deep, and were slid into slots cut along the bottoms of the furnaces. The samples were held upright in the furnaces by the sample holders.

Once the samples were in place a steel door was bolted to the front of the furnace. The back was formed by a piece of insulating board held lightly in place so that an explosion in the furnace would blow it off. Of course, all high-pressure equipment was located in a well-ventilated enclosure behind a barricade. A stream of carbon dioxide, sublimed from dry ice, was fed into each furnace to provide an inert atmosphere. All integral parts of the equipment subject to high temperatures as well as to high hydrogen pressures were constructed of austenitic stainless steel because of its reputed resistance to hydrogen attack. Other parts of the equipment were made of low-alloy steels, and for this reason the pressure was limited to 2,000 atm. to minimize the danger of failure caused by hydrogen embrittlement. It should be pointed out that this pressure is well above any previously reported in the literature for such tests at high temperature with hydrogen gas alone.

Another safety feature incorporated in the design was a set of check valves which were placed in the lines leading to each furnace. The position of these valves is

Fig. 4. Samples of Nichrome Alloy V. Control sample on left, exposed sample on right. Exposed at 2,000 atm. and 475° C. for 4 weeks.

indicated in the schematic diagram of the apparatus shown in Figure 2. They were designed to prevent loss of hydrogen in the event of a sample or equipment failure, and therefore were installed to prevent flow toward the furnaces. They consisted of a valve body and a ⅛-in. ball bearing which was normally held away from its seat by the force of gravity. Any large flow rate, such as would occur when a sample broke, would seat the ball and isolate the furnace from the rest of the system. Since appreciable flow in the direction in which these valves were meant to check was necessary when bringing the samples up to pressure, each of them was by-passed by another line and valve. The by-pass valves were, of course, closed during a run. This design fortunately proved to be entirely satisfactory in practice for several samples did burst under test.

The other parts of the equipment used for the high-temperature runs were of more or less standard design. Hydrogen compression to 1,000 atm. was accomplished by a Norwalk 5-stage compressor. Compression to 2,000 atm., the highest pressure used in the high-temperature runs, was obtained by pumping oil from an intensifier into a vessel of about 22-cu.in. capacity where it displaced hydrogen originally at 1,000 atm. until the desired pressure was reached. This vessel was used also for capacity in the system during a run since the high-temperature tests were of long duration, lasting up to 10 weeks.

### ROOM-TEMPERATURE TESTS

The only additional piece of equipment required for the room-temperature tests was a suitable vessel in which to expose the samples. For these tests the samples were simple strips of sheet metal, 4 in. long, ½ in. wide, and 1/16 in. thick. A bend test was used to determine the extent of hydrogen embrittlement after exposure.

For this work it was desired to use pressures as high as 4,000 atm., and it was clear that the test vessel had to be constructed from materials which were not themselves subject to hydrogen embrittlement. The only information on this subject was a private report which presented evidence to show that the austenitic stainless steels and beryllium-copper are resistant to embrittlement. A high-pressure vessel was available with a capacity of 55 cu.in. constructed of AISI 4140 (low-alloy) steel. With the use of this vessel the apparatus shown in Figure 3 was built. It will be seen that this apparatus was a vessel within a vessel. The inner vessel was a length of standard 1¼-in. pipe made of type 304 stainless steel. One end was sealed by a stainless steel cap, and the other

**Table 1.—General Results of the High-Temperature Tests.**

| Material | Major Constituents in Weight Per Cent C | Fe | Cr | Ni | Mo | V | W | Ti | Other |
|---|---|---|---|---|---|---|---|---|---|
| I. High-Alloy Tool Steels | | | UNAFFECTED | | | | | | |
| Nu-die-V Steel (q, C) | 0.40 | bal | 5. | .... | 1.35 | 1.10 | .... | .... | ..... |
| Rex AA Steel (a, C) | 0.73 | bal | 4. | .... | .... | 1.15 | 18. | .... | ..... |
| 8-N-2 Steel (q, V) | 0.79 | bal | 4. | .... | 8. | 1. | 1.5 | .... | ..... |
| Vasco M-2 Steel (q, V) | 0.65 | bal | 4. | .... | 5. | 2. | 6. | .... | ..... |
| Type 440C SS (a) | 1.04 | bal | 17.0 | 0.26 | 0.45 | .... | .... | .... | ..... |
| II. Ni-Base, Non-Ferrous Alloys | | | EMBRITTLED | | | | | | |
| K Monel (h, I) | 0.15 | ... | .... | bal | .... | .... | .... | 0.45 | Cu = 29 Al = 3 |
| Inconel (r, I) | 0.08 | 7.5 | 15.5 | bal | .... | .... | .... | .... | ..... |
| Inconel X (h, I) | 0.04 | 7. | 15. | bal | .... | .... | .... | 2.5 | Cb = 1 |
| Nichrome Alloy V (r, D) | 0.06 | ... | 20. | bal | .... | .... | .... | .... | ..... |
| Hasteiloy B (r, S) | 0.12 | 5. | .... | bal | 28. | .... | .... | .... | ..... |
| III. High-Alloy, Cr-Ni or Ni-Cr Iron Alloys | | | UNAFFECTED | | | | | | |
| Type 303 SS (a) | 0.15 | bal | 18. | 9. | 0.60 | .... | .... | .... | ..... |
| Type 304L SS (a) | 0.025 | bal | 18.4 | 10.6 | .... | .... | .... | .... | ..... |
| Type 310 SS (a) | 0.16 | bal | 24.9 | 20.5 | .... | .... | .... | .... | ..... |
| Type 347 SS (a) | 0.08 | bal | 18. | 11. | .... | .... | .... | .... | Cb = 10C |
| Nichrome (r, D) | 0.06 | bal | 16. | 60. | .... | .... | .... | .... | ..... |
| Chromax (r, D) | 0.06 | bal | 20. | 35. | .... | .... | .... | .... | ..... |
| IV. Low-Alloy Ti Steels | | | EMBRITTLED | | | | | | |
| Ti Steel (a) | 0.04 | bal | .... | .... | .... | .... | .... | 0.34 | B = 0.02 |
| Ti-Mo Steel (a) | 0.06 | bal | .... | .... | 0.57 | .... | .... | 0.38 | ..... |
| Cr-Ti-Mo Steel (a) | 0.05 | bal | 2.20 | .... | 0.97 | .... | .... | 0.43 | B = 0.026 |
| V. Medium-Alloy Cr Steels | | | EMBRITTLED | | | | | | |
| 5%—Cr Steel (q) | 0.12 | bal | 5.41 | .... | 0.50 | .... | .... | .... | ..... |
| 10%—Cr Steel (q) | 0.10 | bal | 9.57 | .... | 1.10 | .... | .... | .... | ..... |
| VI. Low-Alloy Steels | | | ATTACKED | | | | | | |
| Mild Steel (r) | 0.10 | bal | .... | .... | .... | .... | .... | .... | ..... |
| Max-el 3½ Steel (q, C) | 0.50 | bal | 0.65 | .... | 0.18 | ... | .... | .... | ..... |
| Halvan Steel (q, C) | 0.50 | bal | 1.0 | .... | .... | 0.20 | .... | .... | ..... |
| AISI 4140 Steel (q) | 0.40 | bal | 1.0 | .... | 0.20 | .... | .... | .... | ..... |
| Double Special (a, C) | 1.30 | bal | .... | .... | .... | .... | 3.50 | .... | ..... |

a—annealed
h—age hardened
q—quenched and tempered
r—as received

C—Crucible Steel Co.
D—Driver-Harris Co.
I—International Nickel Co.
S—Haynes-Stellite Co.
V—Vanadium Alloys Steel Co.

by the mushroom closure made of hardened beryllium-copper. The vessel was mounted with the closure downward as shown. Hydrogen was held in the inner vessel while the annular space between the two vessels was full of oil under the same pressure as the hydrogen. In this way hydrogen was confined in a stainless steel vessel under no stress while the pressure vessel itself withstood the pressure but was not in contact with hydrogen.

In operation the annular space was always full of oil and a layer of oil was always kept at the bottom of the inner space. An external line was used to connect the annular space to the inner vessel. The samples to be exposed were placed on the screen near the top of the inner vessel.

The operation of the apparatus is probably best understood with reference to Figure 3. After the vessel had been assembled and sealed with the samples inside, the annular space was filled with oil, and a small amount of oil was pumped into the inner vessel through valve 1. With this valve still open, 1,000-atm. hydrogen was admitted to the inner vessel through valve 2. Valve 2 was then closed and oil was pumped into the inner vessel through valve 1 from the intensifier until the desired pressure was reached. Stainless steel tubing and valves were used wherever the hydrogen pressure was above 1,000 atm.

### Results

#### HIGH-TEMPERATURE TESTS

The results of this investigation are largely qualitative. Indeed, they could hardly be otherwise, for no standard scale for measuring hydrogen damage exists. Various mechanical properties of exposed samples can be measured and compared with like values for samples which were heated only, but from such comparisons one can conclude only that hydrogen damage has been nil, moderate, or severe. Furthermore, if a different property is used as the criterion of damage, different conclusions may result. The mechanical test used in this work was a standard tensile test, the results of which were compared with those for control samples which had been heated in the furnace with the exposed samples but which had not been subjected to hydrogen pressure. The quantities measured were yield strength, ultimate strength, per cent reduction in area, and per cent elongation in 2 in.

Fig. 5. Samples of Crucible Double Special steel. Control sample on right; exposed sample on left; ruptured sample in middle. Exposed for 3 days at 1,000 atm. and 425° C.

In cases where the tensile test showed a detrimental effect of hydrogen, the sample was cut and polished on a cross section and examined microscopically to determine whether it had been chemically attacked.

The twenty-six materials tested at high temperatures are listed along with their compositions in Table 1. In most cases nominal compositions are given. These materials are divided into six groups or classes. The general results of the tensile tests for each group are given in Table 1. Typical numerical results of the tensile test are given in Table 2.

Figures 4, 5, and 6 show several examples of the effects of hydrogen on the test samples. Figure 4 shows two samples of Nichrome Alloy V, which were originally the same, rejoined after having been broken in tension. The sample on the right had been exposed to hydrogen at 2,000 atm. and 475° C. for 4 weeks while the one on the left had been heated only during this period. The effect of hydrogen on the ductility of this material is evident.

Figure 5 shows a sample of Crucible Double Special steel which burst under test after 3 days at 1,000 atm. and 425° C. A second exposed sample, broken in tension, is shown at the left. The dark area extending from the center nearly to the outer edge has been so severely cracked as to appear dark, and shows the area of hydrogen attack in the sample. A control sample is shown at the right.

Fig. 6. Photomicrograph of Max-El 3½. Unetched, ×25. Exposed at 1,000 atm. and 425° C. for 1 week.

Figure 6 is a photomicrograph of the inner edge of a polished but unetched sample of Max-el 3½ steel after exposure for one week at 1,000 atm. and 425° C. The dark lines are cracks which, in general, follow grain boundaries.

**Table 2.—Typical Results of Tensile Tests on Exposed and Control Samples.**

| Crucible Double Special Steel | Control Sample | Exposed Sample |
|---|---|---|
| Tensile strength, lb./sq.in. | 89,400 | 69,900 * |
| % Reduction in area | 27 | nil |
| % Elongation in 2 in. | 18 | 2 |
| **Nichrome Alloy V** | | |
| Tensile strength, lb./sq.in. | 96,100 | 52,000 † |
| % Reduction in area | 50 | 15 |
| % Elongation in 2 in. | 53 | 6 |

* Exposed for three days at 1,000 atm. and 425° C.
† Exposed for four weeks at 2,000 atm. and 475° C.

## materials

#### ROOM-TEMPERATURE TESTS

Results of experiments on room-temperature embrittlement of metals by hydrogen were determined from the average number of 180° bends required to break exposed samples as compared with the number of bends required to break unexposed samples. The samples were strips of sheet metal, and the bends were made with a special apparatus built for this purpose. It was designed to operate on the same principle as a swinging door so that a sample, once secured in the apparatus, could be bent first in one direction and then in the other without removing it. The sample was bent between ¾-in. diam. bearings so that it was rolled first around one bearing by the other and then vice versa. A decrease in the average number of bends required to break exposed samples as compared with unexposed samples was taken as an indication of hydrogen embrittlement.

In all cases the results were determined from averages for several bend tests. The reproducibility of these tests was such that a change of only one or two per cent in the average number of bends required for failure was considered significant. In several cases an in-

**Table 3.—Materials Tested at Room Temperature.**

| Material | Composition in Weight Per Cent | | | | | | |
|---|---|---|---|---|---|---|---|
| | C | Fe | Cr | Ni | W | V | Other |
| Rex M-2 (Crucible Steel Co.) | 0.83 | bal | 4.15 | ..... | 6.4 | 1.9 | Mo = 5 |
| Rex AA (Crucible Steel Co.) | 0.73 | bal | 4. | ..... | 18. | 1.15 | ..... |
| Commercially Pure Nickel | .... | ... | ..... | bal | .... | .... | ..... |
| Monel Metal | 0.16 | 1.4 | ..... | bal | .... | .... | Cu = 30 |
| Inconel | 0.08 | 7.5 | 15.5 | bal | .... | .... | ..... |
| Inconel X | 0.04 | 7. | 15. | bal | .... | .... | Ti = 2.5 |
| Nichrome | 0.06 | bal | 16. | 60. | .... | .... | ..... |
| Incoloy | 0.07 | bal | 21. | 34. | .... | .... | ..... |
| Type 302 SS | 0.11 | bal | 17.76 | 8.74 | .... | .... | ..... |
| Type 410 SS | 0.072 | bal | 13.12 | ..... | .... | .... | ..... |
| Type 430 SS | 0.08 | bal | 17.65 | 0.12 | .... | .... | ..... |
| Cold Rolled Rimmed Steel | 0.08 | bal | ..... | ..... | .... | .... | ..... |
| Cold Rolled Al-Killed Steel | 0.05 | bal | ..... | ..... | .... | .... | ..... |
| Cold Rolled Vitrenamel | 0.03 | bal | ..... | ..... | .... | .... | ..... |
| AISI 1010 Steel | 0.1 | bal | ..... | ..... | .... | .... | ..... |
| AISI 1095 Steel | 0.95 | bal | ..... | ..... | .... | .... | ..... |

dividual test on an exposed sample gave an anomalous result. These were always low. Thus their omission in calculating average results of the bend tests gave conservative indications of the effect of hydrogen. These anomalous low results suggest that hydrogen damage may for one reason or another be unusually great in certain localized areas. Bend tests were made immediately following each run.

Only four room-temperature runs were made owing to lack of time, but this work is continuing. The materials tested are listed in Table 3. Conditions of the runs were as follows: 13 hr. at 2,000 atm., 13 hr. at 3,000 atm., 18 hr. at 4,000 atm., and 1 hr. at 4,000 atm.

The first two steels listed, Rex M-2 and Rex AA, were tool steels. They were tested in the hot-rolled condition, and had a hardness of about 36 on the Rockwell C scale. Thus they were not very ductile to start with, but the results showed a further embrittlement by hydrogen at all pressures used. Moreover, the effect was more severe at higher pressures.

Nickel and several nonferrous nickel-base alloys (Monel metal, Inconel, and Inconel X) were tested, and all showed a degree of embrittlement, Monel metal being the most affected. For example, forty-five bends were required to break unexposed Monel metal, whereas only thirty-one were required for samples exposed for 18 hr. at 4,000 atm. Surprisingly, exposure for 13 hr. at 2,000 atm. produced almost the same degree of embrittlement.

The next group consists of Nichrome, Incoloy, and type 302 stainless steel. These are high-alloy, Cr-Ni or Ni-Cr, iron alloys. As was the case with the high-temperature tests, these materials were not affected by hydrogen. The two stainless steels of the 400 series tested were also resistant to hydrogen embrittlement, but subsequent tests have shown these materials to be embrittled after exposures of several days.

The last five materials listed are plain-carbon steels. Two are of commercial grade, AISI 1010 and AISI 1095. Both of these proved to be susceptible to moderate embrittlement, and both to about the same extent, indicating that the carbon content is not important here. The other three steels were specially prepared by the United States Steel Co. All were low in carbon, sulfur, phosphorus, and silicon. These three steels differed mainly in their preparation. One was a rimmed steel, only partially deoxidized during its manufacture. Such a steel gives off carbon monoxide during and after pouring. The resulting "blow holes" are presumably rolled out and fused during forging, but such a steel probably still contains minute imperfections although its surface should be sound. The second of these steels had been completely deoxidized ("killed") with aluminum during its manufacture. Such a steel is nearly free of blow holes. The third steel, bearing the trade name Vitrenamel, was a particularly low-carbon steel. As can be seen from Table 4, the results obtained for these steels show that the killed steel had a much higher resistance to hydrogen embrittlement than the others. For the killed steel only the severest conditions used, 18 hr. at 4,000 atm., caused any perceptible embrittlement. This exposure lowered the number of bends required for failure from 78 to 61. The other two steels were embrittled at all conditions used, the effect becoming greater as the severity of the conditions increased.

**Table 4.—Representative Results of Bend Tests.**

| Exposure | Bends Required for Failure | | |
|---|---|---|---|
| | Rimmed Steel | Al-Killed Steel | Vitrenamel |
| None | 58 | 78 | 54 |
| 13 hr. at 2,000 atm. | .. | .. | 48 |
| 13 hr. at 3,000 atm. | 39 | 80 | 43 |
| 18 hr. at 4,000 atm. | 21 | 61 | 25 |
| 1 hr. at 4,000 atm. | 51 | 79 | 44 |

### Discussion

In considering the results of the experiments carried out at high temperatures, it is apparent that both temperature and pressure are important variables. In every case where conditions of pressure or temperature were varied, the more severe condition produced the greater effect except, of course, in cases where no effect at all was apparent. This result is in accord with published data.

It is much more difficult to generalize when considering the influence of composition of the materials tested on their susceptibility to hydrogen attack. Of the metals apparently unaffected by hydrogen at the conditions of exposure, four were high-alloy tool steels (Group I). All contained appreciable amounts of alloying elements which form relatively stable carbides, and it is presumably to this that they owe their resistance to attack. These materials were, however, quite brittle to start with, and it is doubtful that further embrittlement by hydrogen would be detected by a tensile test. These comments apply as well to type 440C stainless steel. In this connection it should be noted that the two tool steels tested at room temperature

proved to be susceptible to hydrogen embrittlement as indicated by bend tests. It is possible that the bend test is a more sensitive test for embrittlement than the tensile test. Furthermore, one sample of Nu-Die-V tool steel cracked at 2,000 atm. and low temperature during the start-up of a high-temperature run. Since there was no other apparent reason for this failure, it is probable that it is attributable to hydrogen embrittlement. These materials are therefore not now recommended for use with high-pressure hydrogen.

The five nickel-base, nonferrous alloys (Group II) tested at temperatures of 450 to 500° C. were all adversely affected by hydrogen. This is perhaps surprising since these materials are special high-temperature alloys. It is not possible, however, to say that a chemical attack occurred since microscopic examination showed almost no evidence of it. Furthermore, all had low-carbon contents and contained relatively large amounts of elements which form stable carbides. The effect of hydrogen on these materials seems to be embrittlement rather than attack. It is to be noted too that the nickel-base alloys tested at room temperature showed susceptibility to hydrogen embrittlement.

Six high-alloy, Cr-Ni or Ni-Cr, iron alloys, including four austenitic stainless steels, Nichrome, and Chromax were tested at high temperature, and none was adversely affected. If anything, the effect of hydrogen was beneficial, for in every case where one of these materials was exposed at 2,000 atm., the yield and ultimate strengths were slightly increased without any loss of ductility. In addition, the materials of this type tested at room temperature were not embrittled. The conclusion is that in so far as can be determined from these results, austenitic stainless steels are entirely satisfactory for use with high-pressure hydrogen.

Several low-alloy steels containing titanium were tested at high temperature. They all had low carbon contents, and their most important alloying element was titanium, which Naumann (*4*) reported to give a very high resistance to hydrogen attack when present in an amount four times the carbon content. All of these steels had a Ti/C ratio greater than four; so one would expect them all to have high resistance to attack. This is apparently the case. However, two of these steels did show some embrittlement without any corresponding loss in strength, and it should be noted that the other one was tested at somewhat milder conditions. An attempt was made to test another steel of similar composition having a Ti/C ratio of only 2.7, but this was unsuccessful. Both samples subjected to hydrogen pressure cracked during the start-up of the run. Whether these failures were caused by hydrogen embrittlement or were the result of flaws in the steel cannot be surely stated, but the former is certainly a possibility.

The two chromium steels tested were embrittled, but apparently not attacked. The chromium contents were sufficient to tie up the carbon in the form of stable carbides which resist attack.

Several low-alloy steels—Max-el 3½, Halvan, AISI 4140, and Crucible Double Special—and a plain-carbon steel, which were not expected to resist hydrogen attack, were exposed at high temperatures. None of these steels had an alloy content sufficient to tie up all the carbon as stable carbides. All of them were severely attacked with the exception of the AISI 4140 samples, which were, however, badly embrittled at the relatively mild conditions at which they were exposed.

In addition to the results which were determined deliberately mention should be made of those which were quite inadvertently obtained. Two pieces of equipment made of low-alloy, hardened steels failed at room temperature under a pressure of 3,000 atm. These results, quite unexpected at the time, initiated us to the room-temperature effects of hydrogen on steel. There seems to be no other explanation for these failures than hydrogen embrittlement. One of the pieces which failed was a check valve which was made of hardened AISI 4140 steel. A section was cut from this valve, and was polished and etched for microscopic examination. Several fine, radial cracks were found. One of these is shown in the photomicrograph of Figure 7. This steel had a fine structure which does not show grain boundaries, and the crack does not seem to follow any other structural boundaries of the steel.

It should also be mentioned in connection with hydrogen embrittlement that no trouble was experienced with any equipment made of low-alloy steels at hydrogen pressures below 2,000 atm. Moreover, the materials used for contact with 4,000-atm. hydrogen, i.e., austenitic stainless steel and beryllium-copper, proved to be satisfactory.

The hydrogen used in this work was water-pumped hydrogen of commercial purity. No attempt was made either to purify or to dry it. It was felt that the results of these tests would be of greatest practical value if the hydrogen used was that which is commercially available.

## Conclusions

Hydrogen at pressures as low as 2,000 atm. can cause dangerous embrittlement of metals even at room temperature. At high temperatures also hydrogen can cause embrittlement, and in addition, may attack steel chemically. Probably the most suitable material for use with high-pressure hydrogen is austenitic stainless steel.


## Acknowledgment

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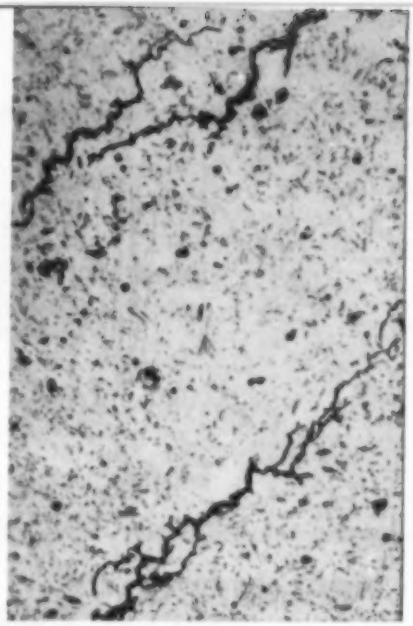

Fig. 7. Photomicrograph of check valve. AISI 4140 steel. Picral etch, ×250. Hardened and tempered to Rockwell C 35.

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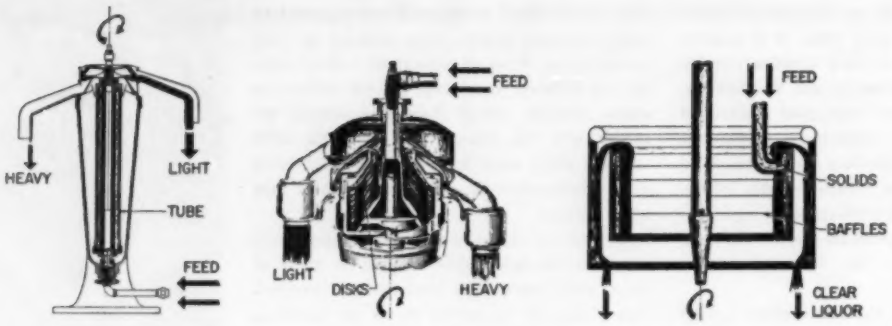
*Presented at A.I.Ch.E. 47 annual meeting, New York.*


**materials**




TUBE
BREAKING EMULSION

DISK
SEPARATING LIQUIDS

BASKET
CLARIFYING LIQUOR

Fig. 1. Vertical solid-bowl types — tube, disk, and basket.

# PRELIMINARY SELECTION OF centrifugal equipment

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Centrifugal equipment frequently will perform mechanical separations which cannot be done by other equipment or will compete successfully with alternatives in performing a job at low labor cost, small space requirements, minimum holdup time, and maximum materials recovery. The types and manufacturers of centrifugal equipment and successful and economical applications are constantly increasing.

To assist the process engineer in making a selection of centrifugal equipment for mechanical separations on a commercial scale of liquid-liquid and liquid-solid systems, a survey of the equipment available from the various sources of the United States has been made. The information contained in this survey will not permit a final selection of equipment. The aim is to assist in deciding whether centrifugal equipment is applicable to a given mechanical separations problem, and if so, to reduce to a minimum the types of centrifugal equipment on which detailed studies should be made.

### Equipment Data

For comparison purposes centrifugal liquid-liquid and liquid-solid separating equipment is divided into two classifications, the solid bowl and the perforate basket. The latter is sometimes referred to as the centrifugal filter. A discussion of the mechanical and capacity features of the various models is given, together with schematic diagrams showing the distinguishing features of each type. Tables 1-4 summarize the information for a preliminary centrifugal equipment selection. These data show which of the various processes performed by centrifugal equipment can be done by each of the machines, list interesting cost and mechanical features for comparison, and name the United States sources of each machine.

Table 5 lists typical high- and low-capacity data from commercial applications of each of the types of centrifugal equipment. This information will serve as a guide for the engineer in his preliminary design.

### Discussion

Many types of centrifugal equipment are available, and all manufacturers aim high in providing operating convenience, sturdy construction, high capacity, reliability, low maintenance, accessibility, safety, and economy.

To satisfy this aim, such features as automatic timers, overload protection, alloy and rubber-lined construction, vapor-tight hoods, dismantling devices, and braking are common. Where applicable, these features and others are available on all types, and, except for automatic controls, are not commented on in this paper.

For discussion purposes centrifugal equipment may be divided into two types: the solid bowl and the perforate basket. Each of these may be subdivided according to whether the bowl or basket is vertical or horizontal.

### A. SOLID BOWL

Most tubular- and disk-bowl machines are restricted to light slurries although nozzle-equipped disk machines, the vertical solid basket, and all three of the horizontal solid-bowl types can handle slurries of relatively high solids content. Some machines must be shut down in order to clean out the accumulated solids; others have various types of automatic discharges which make them more suitable for the heavier slurries. Washing may be provided in special disk and vertical solid-basket machines and in all three horizontal solid-bowl types.

#### 1. Vertical Solid Bowl

Several modifications of the vertical solid bowl are available: the tubular bowl, the disk type, and the solid basket. These are shown in Figure 1. As noted in Table 1, all three types may be used to classify, to clarify, to concentrate a slurry, and to perform liquid-liquid separations. Most liquid-liquid separation and emulsion-breaking jobs are performed by the tubular bowl and disk types.

The internal construction of the tubular bowl may provide for multiple passes. On the other hand, it may feature a filter cylinder for material which is fine, present in low concentration, or has the same specific gravity as the liquid.

Figure 1 shows the separation of two liquids in the vertical solid bowl. The heavy liquid is thrown to the wall of the tubular centrifuging chamber, the light liquid rides on top of it, and both pass to separate discharge devices at the top.

The diagram of the disk machine shows its disk assembly which greatly increases its capacity. Solids do not have to travel far through the liquid before they come up against a disk and slide down it to the periphery of the bowl

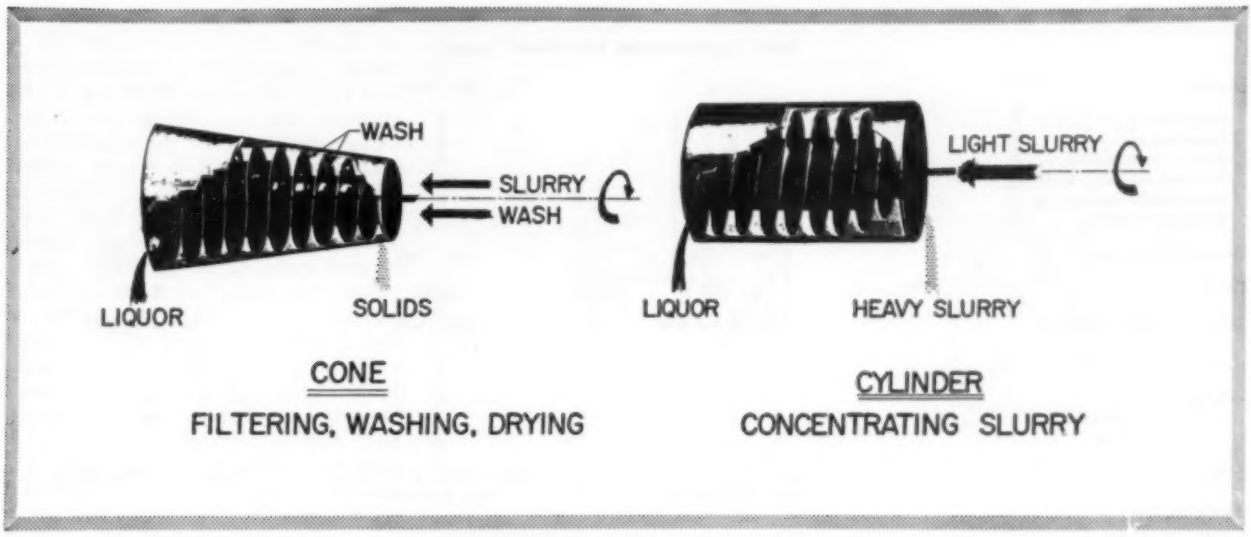


Fig. 2. Horizontal solid-bowl types—cone, cylinder.

where they are either held for manual removal or are discharged automatically by nozzles. The discharge of solids from the vertical solid-tube and vertical solid-basket types is intermittent and manual. All these machines are designed for easy access; in fact, solids can be removed from the vertical solid-basket machine without dismantling it.

Where the solids content of the slurry is relatively high, the vertical tube is at a disadvantage because of its small solids-holding volume, particularly in comparison with the vertical solid basket. It finds its most successful applications in those difficult polishing jobs where its high centrifugal force can be used to best advantage.

Where washing is required, special disk or special solid-basket machines may be used. Since the vertical solid-bowl machines produce a wet discharge, auxiliary equipment will be needed if the solids are to be dried.



**Table 1.—Vertical Solid-Bowl Types**

| Function | Tube | Disk | Basket |
|---|---|---|---|
| Classification | X | X | X |
| Clarification | X | X | X |
| Slurry concentration | X | X | X |
| Filtering, washing & drying | | | |
| Liquid-liquid separation | X | X | X |
| Emulsion breaking | X | X | |
| Gravities Developed | 13,200–62,400* | 700–9500 | 500–2000 |
| Driver hp. | ⅛–3 | Fractional to 125 | 2–40+ |
| Capacity: Feed (gal./hr.) | 3–1600 | 30–18,000 | 400–6000 |
| or Solid prod. (tons/hr.) | | To 9** | To 0.75 |
| Relative Cost High | | X | |
| Medium | X | X | X |
| Low | X | | |
| Dimensions | 1¾–6-in. diam. Length to 5 ft. | 10½–48-in. diam. Height = diam. (approx.) | Basket: 12–48-in. diam. Depth = ½ to 4.7 diam. |
| Available From | | | |
| American Tool & Machine | | | X |
| Bird | | | X |
| De Laval | | X | |
| Fletcher | | | X |
| Heyl-Patterson (Reineveld) | | | X |
| Merco | X | X | |
| National Acme | X | | |
| Sharples | X | X | |
| Squier | | | X |
| Tolhurst | | | X |
| Western States Machine Co. | | | X |

* To 100,000 Gees in lab machine, to 500,000 in ultracentrifuge. ** Discharged in heavy slurry.

**Table 2.—Horizontal Solid-Bowl Types**

| Function | Cone | Cylinder | Basket |
|---|---|---|---|
| Classification | X | X | X |
| Clarification | X | X | X |
| Slurry concentration | X | X | X |
| Filtering, washing & drying | X | X | |
| Liquid-liquid separation | X | X | X |
| Emulsion breaking | | | |
| Gravities Developed | 600–2100 | 500–2100 | 100–2000 |
| Driver hp. | 7½–150 | 10–75 | 5–400 |
| Capacity: Feed (gal./hr.) | To 24,000 (Filtrate) | 600–1500 | 4000–18,000 |
| or Solid prod. (tons/hr.) | To 60 | | |
| Relative Cost High | X | X | X |
| Medium | X | X | X |
| Low | | | |
| Dimensions | Large diam.: 14–54 in. Length: 24–70 in. | 14-in. diam. × 20 in. long & larger | Basket: 16–100-in. diam. |
| Available From | | | |
| Baker-Perkins | | | X |
| Bird | X | X | |
| Centrifuge Mechanical Equipment | X | | |
| Heyl-Patterson (Reineveld) | | | X |
| Sharples | X | X | |
| Tolhurst | X | | |

2. Horizontal Solid Bowl

As is possible with the vertical solid-bowl machines and as Table 2 shows, the horizontal solid bowl may be used to classify, to clarify, to concentrate a slurry, and to separate liquid-liquid mixtures. Also, this type may be used to wash and dry its solid product. The continuous classification and concentration of slurries are important uses of the cone and cylinder machines. When the solids are relatively large in particle size, the horizontal solid-bowl machine will clarify liquors at practical rates in spite of its lower centrifugal force, and may be used also to wash and dry. It will be noted in Table 2 that this machine develops a high of approximately 2,000 Gees, whereas the smaller vertical solid bowl runs as high as 62,400. Where both a large capacity and a clear liquor are required, it may be practical to use the two types in series.

In some applications frothing will occur. In this event, there is danger of floating solids over with the filtrate, and thus polishing may be needed.

**Table 3.—Vertical Perforate-Basket Types**

| Function | Batch Basket | Continuous Cone |
|---|---|---|
| Classification | | X |
| Clarification | | |
| Slurry concentration | | |
| Filtering, washing & drying | X | X |
| Liquid-liquid separation | | |
| Emulsion breaking | | |
| Gravities Developed | 500–2000 | 500–2000 |
| Driver hp. | 2–40+ | 3–40 |
| Capacity: Feed (gal./hr.) | | To 6000 |
| or Solid prod. (tons/hr.) | 1–10 | 1–10 |
| Relative Cost High | | |
| Medium | X | X |
| Low | | |
| Dimensions | Basket: 12–84-in. diam. Depth = ½ to 4.7 diam. | Large end: 8–16-in. diam. Length of cone: 6–13 in. |
| Available From | | |
| American Tool | X | |
| Bird | X | |
| Fletcher | X | |
| Heyl-Patterson (Reineveld) | X | X |
| Merco | | X |
| Squier | X | |
| Tolhurst | X | |
| Western States Machine Co. | X | |

A rotating screw exists in two of the horizontal solid-bowl types—the cylindrical bowl and the conical bowl (see Figure 2). The screw rotates approximately 20 rev./min. fewer than the bowl and can handle relatively large amounts of solids. In general, the conical bowl will be used for firm-bodied or crystalline-type solids, whereas the cylindrical bowl will be employed for relatively soft or plastic solids. Washing may be provided on both of these and also on the horizontal solid basket. Where the solids are relatively free-draining, such as sodium chloride, the washing is generally effective and may be more effective than a vacuum filter and may even use less wash. To wash finely divided solids, such as calcium carbonate, it may be necessary to repulp (sometimes in the centrifuge) and centrifuge again. As a rule of thumb, successful washing may be expected in the horizontal conical solid bowl if the solids product contains no more than 40% moisture. The horizontal solid basket is not shown on Figure 2, but has the same process features and operating characteristics as the vertical solid basket illustrated in Figure 1. Its chief application is in the clarification of liquors where its relatively large solids-holding capacity is an advantage.

### B. PERFORATE BASKET

The major field of application for the perforate-basket centrifuge is the separation of coarse solids at high slurry concentrations and for those jobs requiring several washes or a dry product. A controlling feature in the capacity of such a machine is the filtrate drain rate. Where fines are encountered, a filter-aid precoat may be helpful. To ensure fastest draining, the residual heel of solids left after each batch may require a conditioning wash. To do this, the batch machine may incorporate a heel wash in the cycle. Owing to their method of operation, this feature is not available on the continuous horizontal perforate types. They thus find their best application in the coarser materials which are less likely to blind the screen.

A check of Tables 3 and 4 reveals the fact that the batch machines fall into the perforate-basket category. Where small amounts of several different materials are to be handled on the same machine, manual operation and continuous observation may be advantageous. Where economics and the process call for it, the cyclic operation of both horizontal and vertical batch machines may be completely automatic. This feature is the rule on the horizontal-basket machines and is becoming increasingly common on the vertical models.

An outstanding feature of perforate-basket machines is the dryness of the solids which are produced.

For discussion purposes, perforate-basket machines are divided into vertical and horizontal types as were the solid bowl machines.

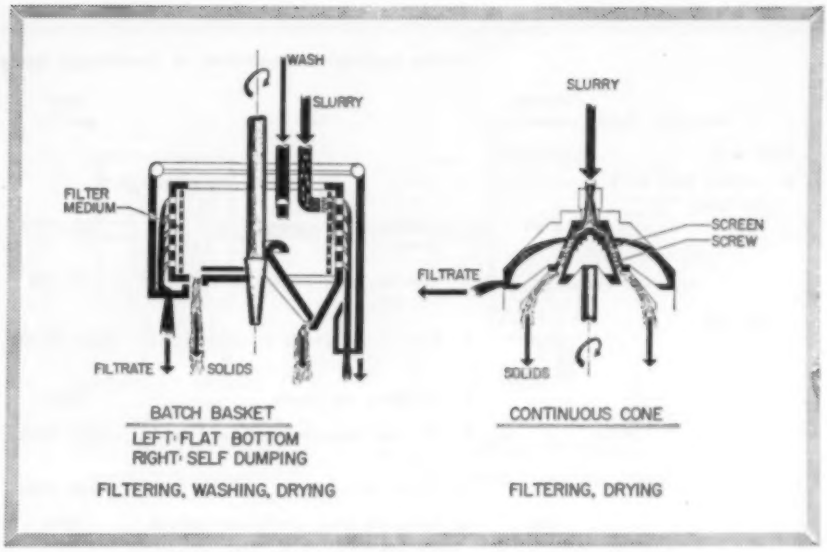


**Fig. 3. Vertical perforate-basket types—batch basket, continuous cone.**

#### 1. Vertical Perforate Basket

This type is procurable from more manufacturers than is any other industrial centrifuge. Available in a wide variety of basket dimensions, it may have either a top or bottom drive, and either an open or closed bottom.

Figure 3 shows this machine schematically. This is a batch machine on which one or more washes, which may be collected separately if desired, may be employed. Adaptation of this type of machine to automatic control has been completed recently by some manufacturers, and it is now possible to control automatically the complete cycle, including feeding and discharging. The bowl does not rotate at a constant speed, but is slowed down to approximately 50 rev./min. for unloading, and in some cases is reversed. Because of this slow speed unloading, there will be less crystal breakage in this type of machine than in the horizontal type described hereinafter. With the manually controlled models, where the loading is done by hand, it



**Table 4.—Horizontal Perforate-Basket Types**

| Function | Batch Basket | Continuous Basket | Continuous Cylinder |
|---|---|---|---|
| Classification | | X | X |
| Clarification | | | |
| Slurry concentration | | | |
| Filtering, washing & drying | X | X | X |
| Liquid-liquid separation | | | |
| Emulsion breaking | | | |
| Gravities Developed | 100–2000 | | 500–2100 |
| Driver hp. | 5–400 | | 10–75 |
| Capacity: Feed (gal./hr.) or Solid prod. (tons/hr.) | 1–12 | ½–28 | 300–15,000<br>½–20 |
| Relative Cost High | X | X | X |
| Medium | | | X |
| Low | | | |
| Dimensions | 16–100-in. diam. | | 14-in. diam. × 20 in. long & larger |
| Available From | | | |
| Baker-Perkins | X | X | |
| Bird | | | X |
| Centrifuge Mechanical Equipment | | | X |
| Cleaver-Brooks (Escher-Wyss) | | X | |
| Heyl-Patterson (Reineveld) | X | | |
| Sharples | X | | |

**Table 5.—Typical Capacities of Centrifugal Equipment**

| Equipment Type | Capacity Level | Job | Feed gal./hr. | Product tons/hr. | Comments |
|---|---|---|---|---|---|
| A. Solid Bowl | | | | | |
| 1. Vertical Solid Bowl | | | | | |
| (a) Tube | | | | | |
| | High | 1. Insulating oil; remove dirt and water. | 1000–1200 | | |
| | Low | 1. Chewing gum; remove solids from raw gum. | 60–100 | | |
| (b) Disk | | | | | |
| | High | 1. Corn starch; clarify & concentrate. | 7200–18,000 | | Solids handled: About 9 tons/hr. at 18,000 gal./hr. feed |
| | | 2. Insulating oil; clarify. | 1800 | | |
| | | 3. Fish oils; separate water and meal from oils. | 2000–2500 | | |
| | | 4. Kaolin clay; classify. | 1500–2000 | | |
| | Low | 1. Pineapple juice; clarify and remove oversize solids. | 1000 | | |
| | | 2. Vegetable oil; degumming. | 670 | | |
| | | 3. Rubber latex; concentrate. | 160 | | |
| (c) Basket | | | | | |
| | High | 1. Distillery slops; removing solids. | 6000 | | 48-in. diam. basket |
| | Low | 1. Tin plating solution; clarify. | 1800 | | 40-in. diam. basket |
| | | 2. Molasses; separate calcium sulfate. | 1500–2000 | | Slurry is 2½% solids. |
| | | 3. Liquid cement; removing solids. | 1000 | | 40-in. diam. basket |
| 2. Horizonal Solid Bowl | | | | | |
| (a) Cone | | | | | |
| | High | 1. PVC suspension resin. Separate solids and wash. | | 2 | Bowl 32-in. diam. × 50 in. long |
| | | 2. Fish liquor; remove sludge. | 3600 | | |
| | Low | 1. Drilling mud; recover barites, remove light solids, reduce viscosity. | 600–800 | | Bowl 14-in. diam. (Large end) × 22 in. long. |
| (b) Cylinder | | | | | |
| | High | 1. Grape juice; depulp. | 1500 | | Bowl 14-in. diam. × 19¾ in. long. |
| | Low | 1. Antibiotics; clarify extracts. | 600 | | |
| (c) Basket | | | | | |
| | High | 1. Starch; washing potato starch milk to remove proteins. | To 17,000 1½° Be feed. Output 8 to 12° starch mlik. | | 67-in. diam. basket 737 Gees |
| B. Perforate Basket | | | | | |
| 1. Vertical Perforate Basket | | | | | |
| (a) Batch Basket | | | | | |
| | High | 1. Sugar; filtering from mother liquor. | | 8<br>5 | 48-in. diam. basket<br>40-in. diam. basket |
| | Low | 1. Ferrous sulfate; filtering from mother liquor. | | 1 | 40-in. diam. basket |
| (b) Continuous Cone | | | | | |
| | High | 1. Synthetic ammonium sulfate; separation from mother liquor; slurry solids content: 50%. | | 0.6 to 6 | 800 Gees; product rate depends on size of machine. |
| | | 2. Starch; removing fiber from starch suspension. | 6000 | | Cone 16-in. diam. (Large end) |
| 2. Horizontal Perforate Basket | | | | | |
| (a) Batch Basket | | | | | |
| | High | 1. Ammonium sulfate; filtering from aqueous mother liquor. | | 26–28 | 48-in. diam. basket |
| | Low | 1. p-dichlorobenzene, filter and wash. | | 1 | 27-in. diam. basket |
| (b) Continuous Basket | | | | | |
| | High | 1. Synthetic ammonium sulfate; filtering from mother liquor. | | 4–6 | 27-in. diam. basket 1–2% water in product. |
| | | 2. Sodium chloride; filtering from aqueous mother liquor; slurry solids content: 50%. | | 25 | 48-in. diam. basket 2% water in product. Solids: 40% + 35; 99% + 100. |
| (c) Continuous Cylinder | | | | | |
| | High | 1. Glycerine; separate and wash salt. | | 2 | Bowl 24 in. × 24 in. |

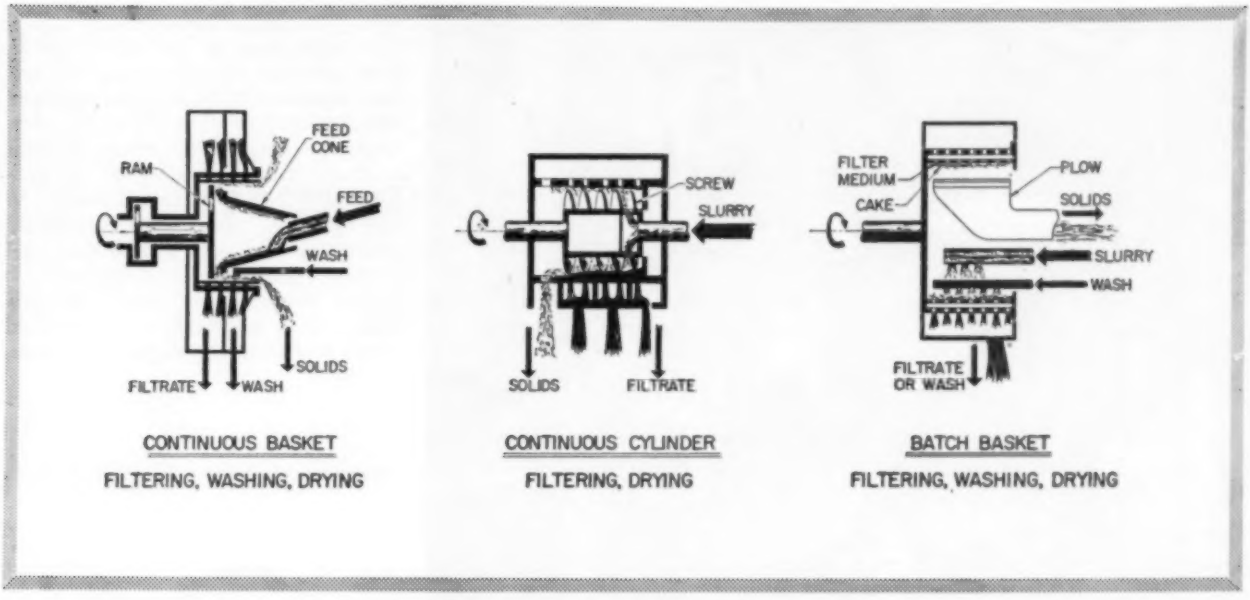


Fig. 4. Horizontal perforate-basket types—continuous basket, continuous cylinder batch basket.

is possible to handle even short-term fluctuations in slurry concentrations. It is customary for one operator to handle from 3 to 6 of these machines, depending upon the degree of automatic control.

A special modification of the vertical perforate basket appears in a conical shape. Slurry is fed continuously into the small-diameter top and is subjected to increasing drying force for the greatest drying efficiency. In its efficiency and flexibility of washing, this machine lies between the continuous solid-bowl and the batch basket machines.

#### 2. Horizontal Perforate Basket

The horizontal perforate basket is available in both batch and continuous forms (see Figure 4). The batch machine is usually supplied with completely automatic controls, and thus requires a minimum of labor. Changes in composition of the feed slurry or the draining characteristics of the solids can be accommodated by adjustments on the cycle timers. With suitable diversion valves in the liquid discharge it is possible to obtain a sharp separation between mother liquor and wash liquors. The batch machine can incorporate as many washes as are needed. In distinction from the vertical perforate-basket type, the horizontal-bowl type operates at a constant bowl speed. As a result, slurry attrition is somewhat more severe at the impact of feed and knife. One exception to the full-speed discharge reduces to ¼ speed for unloading. This reduces solids attrition but decreases the capacity of the machine.

The perforate basket of this type of machine supports a filtering screen, which in turn supports a heel of the material being filtered. This heel may require periodic conditioning to prevent blinding and deterioration of the filtering rate with consequent loss in capacity.

The continuous horizontal perforate-basket centrifuge is available in two types: the hydraulic-ram and the horizontal-cylinder type.

To effect continuous operation of the perforate-basket centrifuge, some models feature a hydraulic ram which moves back and forth inside the basket, pushing the solids off the end. The screen is composed of metal strips laid in the direction of flow of the solids. A conical feed tube may be used in this type of centrifuge, which results in less slurry attrition in feeding this machine than is suffered on the batch-type horizontal basket. Washing (but with generally imperfect separation of mother liquor and wash) may be incorporated in the hydraulic-ram machine, and minor fluctuations in feed supply will not prevent the production of a dry product.

Like the solid horizontal cylinder, the perforate horizontal cylinder machine incorporates a scroll to move the solids. One or more washes, which may be kept separate, can be provided. Washing and drying are both less effective than on the batch basket; drying is less effective than on the vertical perforate cone. As is the case with the hydraulic-ram type just referred to, the horizontal perforate machine finds its most successful application in removing the coarser solids from liquors which do not have to be recovered completely.



### Conclusion

A sample problem concerning the clarification of a liquid will illustrate the contents and the use of the survey described in this paper. Tables 1 and 2 show that clarification may be effected by all solid-bowl types: the vertical tube, disk bowl, and solid basket; and the horizontal cone, cylinder, and solid basket. Suppose that the liquid to be clarified contains very fine solids in small quantities (less than 0.5%), that no washing is required, and that a flow rate of 100 gal./hr. is to be handled. First one can state that very fine solids will require high centrifugal forces to separate them from the supporting liquor at a reasonable rate. (Of course, the difference in density between solids and liquor will also affect this.) Further examination of the tables reveals that the vertical tube and the vertical disk bowl develop the highest centrifugal force. Since small quantities of solids are involved and no washing is required, either type may be suitable. Also, the capacity range of both covers the required rate of 100 gal./hr.

At this point in the problem, the survey has served its purpose of indicating the existence of centrifugal equipment which might solve the clarification problem, and of reducing the types on which a detailed investigation, including pilot tests on laboratory machines and economic analyses of centrifugal and alternative equipment, will be conducted.

*Presented at A.I.Ch.E. meeting, Louisville, Ky.*

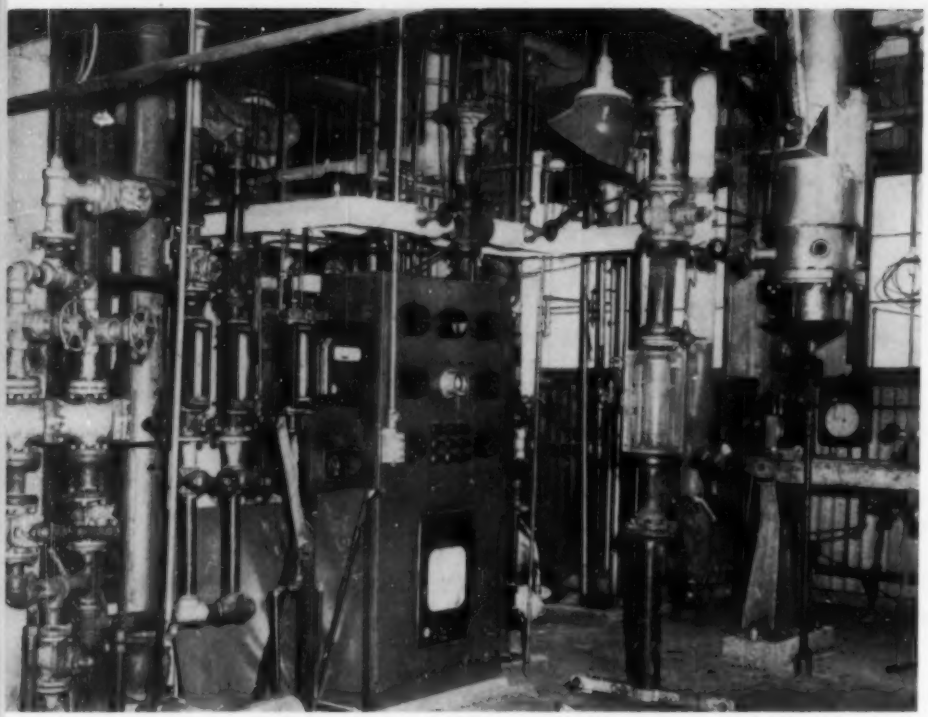

Fig. 2. Details of equipment at operating level.

# THE CONCENTRATION OF GR-S latex IN A TURBULENT-FILM EVAPORATOR

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For many latex manufacturing applications it is necessary that the total solids content of the raw latex be greater than 60%. Hevea (natural) latex is concentrated from the level of about 40% total solids at which it is collected from the tree (Hevea brasiliensis) to approximately 60% total solids by either creaming or centrifuging. The GR-S-type synthetic rubber latices, particularly those so-called "cold" latices which are emulsion copolymerized at temperatures lower than 50° F., cannot presently be made in the polymerization vessel to a total solids greater than about 40%. Some method of concentrating these GR-S latices to 60% solids then is necessary.

The GR-S latices are not directly adaptable to the concentrating techniques of creaming and centrifuging long practiced with Hevea latex. Early work on the heat concentrating of GR-S latex (*1*) showed this method to be practical and several large installations were made to keep pace with the steadily increasing demand for 60% total solids, cold GR-S latices.

In current commercial practice, the typical equipment for GR-S latex heat concentration consists first of a vessel connected to a condenser and maintained at an absolute pressure of about 100 mm. Hg. This vessel is initially partially filled with the 40% solids latex. From the bottom of the vessel, latex is continually pumped through a heat exchanger to bring it above the equilibrium temperature in the vessel. The heated latex is then continually returned to the vessel where equilibrium conditions are reestablished with the resultant flashing of some of the water into vapor which passes to the condenser. This cycle of pumping, heating, and flashing is continued until all of the initial charge of latex has been concentrated to 60% total solids. The product is then removed from the vessel, a new charge of 40% total solids latex is brought in, and the process is repeated.

The equipment now used is of great size and weight. A complete shutdown is required at frequent intervals so that the latex may be withdrawn and a new charge brought in. Unit capital, maintenance and operating costs are high. In addition, latex entrainment in the flashed vapor results in frequent fouling of the vapor lines and condensers. Improved equipment for commercially concentrating GR-S latex is needed.

The turbulent-film evaporator * appeared to offer the desirable features of small size, once-through operation, easy cleaning, and positive entrainment control. A size No. 2 Turba-Film unit was installed in the GR-S pilot plant operated by Naugatuck Chemical Division of United States Rubber Company in Naugatuck, Connecticut. An engineering study of this equipment was made, its behavior in concentrating commercial GR-S latices was observed, and an extended run, simulating actual plant operating conditions, was carried out.

**Equipment**

The No. 2 Turba Film unit consists first of a vertical cylindrical jacketed evacuated evaporating section 1 ft. I.D. by 3 ft. long. Centered in this cylinder is a flat-bladed agitator, the four blades of which revolve at 800 rev./min. within $\frac{1}{32}$ in. of the highly polished stainless steel wall of the jacketed section. Feed enters at the top of the evaporating section and is immediately thrown against the heated wall. The dwelling time of an average droplet of feed in the evaporator is about 45 sec. During this time the droplet is always part of a turbulent boiling film on the inner wall of the heated shell. The finished, concentrated product continually flows by gravity to the bottom of the chamber from whence it passes to a receiver.

The vapors from the evaporating film pass upward along the agitator shaft. Mounted above the evaporating section is the separating section. The flat blades of the agitator extend upward into this section and turn within a bundle of radially mounted fins. These arrest the entrained droplets of liquid thrown from the rotating blades. The droplets coalesce and fall back into the evaporating section while the vapor passes out above the separating section. The No. 2 Evaporator has a capacity to evaporate 300 lb. water/hr. at 75 mm. Hg abs. by the use of jacket steam at 30 lb./sq.in. gauge.

The vapors from the evaporator were passed to a vertical vapor-tube shell and tube condenser having 152 sq.ft .of condensing surface. A surface condenser was used so that the condensate might be collected and weighed for the engineering evaluation of the equipment. The condensate was run by gravity into an evacuated receiver. A bullseye was installed in the condensate line to permit visual inspection of the stream for evidence of latex carry-over. The condensate receiver was connected to a two-stage steam ejector which kept the whole system under vacuum.

The feed latex was prepared in an open 600-gal. agitated tank and was drawn into the evaporator by pressure difference. Strainers and rotameters were installed in parallel in the latex feed line. The latex flow rate was regulated by a manually controlled air-operated rubber diaphragm valve placed as close to the shell of the evaporator as possible to minimize flashing in the feed pipe.

Steam pressure on the jacket was controlled automatically by an air-operated pressure-control valve. The steam condensate was collected in a tank where it could be measured.

The concentrated latex, after passing through the evaporator, dropped into a receiving tank. A section of glass pipe was installed in the concentrated latex transfer line to permit observation. A double-valved sampling device was also installed in this line so that concentrated latex samples could be taken during a run without disturbing the vacuum.

Instruments were provided to indicate the temperatures of latex feed, latex discharge, con-

* Turba-Film Evaporator—T/M reg., Rodney Hunt Machine Company, Orange, Mass.

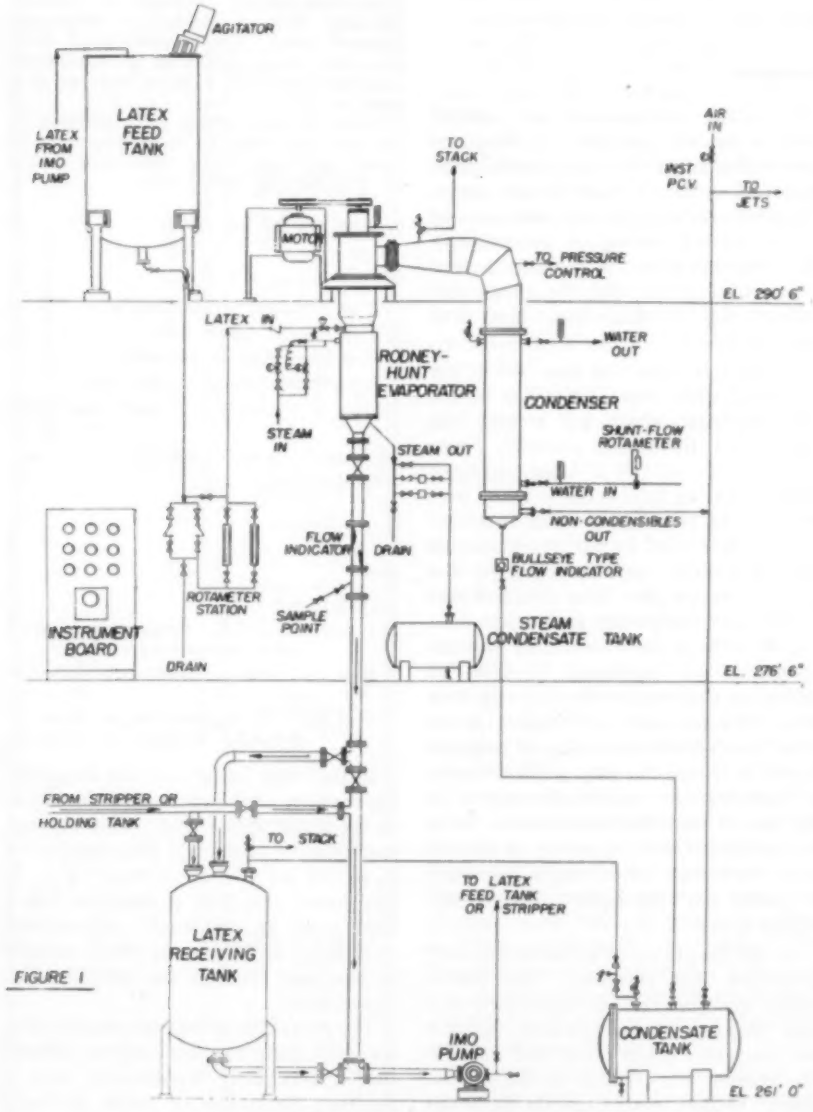


FIGURE 1

Fig. 1. Flow diagram, latex concentration at pilot plant.

**Table 1.—Initial Runs**

| Run No. | Agitator speed | Latex Feed $S_1$ Total solids, % | Latex Feed $R$ Flow, gal./min. | Latex Concentrate $S_2$ Total solids, % | Latex Concentrate Temp., ° F. | Vacuum, in. gauge | Vapor temp., ° F. | Steam jacket press. lb./sq.in. gauge | Steam jacket temp., ° F. | $E$ Water evaporated lb./hr. | $Q$ M B.t.u./hr. | $\Delta T$, ° F. | $U$ B.t.u./(hr.) (sq.ft.)(° F.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 600 | 34.1 | 4.0 | 45.4 | 95 | 27.1 | 92 | 28 | 271 | 400 | 417 | 179 | 259 |
| 2 | 600 | 34.1 | 1.9 | 56.0 | 85 | 28.4 | 83 | 20 | 259 | 363 | 380 | 176 | 240 |
| 3 | 600 | 34.1 | 2.2 | 58.9 | 87 | 28.4 | 85 | 20 | 259 | 435 | 475 | 174 | 303 |
| 4 | 800 | 34.1 | 2.2 | 62.3 | 87 | 28.4 | 85 | 20 | 259 | 489 | 511 | 174 | 326 |
| 5 | 800 | 34.1 | 2.3 | 61.6 | 91 | 28.2 | 87 | 21 | 260 | 505 | 528 | 173 | 340 |
| 6 | 800 | 37.5 | 2.4 | 56.0 | 90 | 28.5 | 87 | 20 | 259 | 390 | 408 | 172 | 254 |
| 7 | 1100 | 37.5 | 2.5 | 57.1 | 90 | 28.5 | 89 | 20 | 259 | 421 | 440 | 170 | 288 |
| 8 | 1100 | 37.5 | 2.5 | 58.3 | 90 | 28.5 | 87 | 20 | 259 | 438 | 457 | 172 | 296 |

denser water inlet, condenser water outlet, and evaporated vapor. The vacuum on the equipment was both recorded and controlled by an instrument which actuated a pressure-control valve through which air was bled into the system in order to hold the desired vacuum at a maximum deviation of 1 mm. Hg from the set point. The rate of flow of condenser water was indicated on a shunt-flow rotameter. An ammeter indicated the current passing to the motor driving the evaporator agitator. A gauge indicated steam-jacket pressure.

Figure 1 is an elevation layout of the equipment. Figure 2 is a photograph at the operating level showing, from left to right, the feed latex strainers, rotameters, condenser flow indicator, steam-jacket pressure controller-indicator, instrument panel, concentrated latex line with sight glass and sample point, and condenser with condensate line and bullseye.

### Operation

A typical experimental run started with a known quantity of latex at measured total solids content in the latex feed tank with all other tanks empty. The pressure in the system was reduced to the desired setting of the pressure recorder-controller. Water was turned into the condenser and the evaporator agitator was started. Latex flow was then started.

As soon as latex was observed in the section of glass pipe in the line to the receiving tank, steam was turned into the jacket at the desired pressure. Since the viscosity of GR-S latex increases with increasing total solids content, preliminary adjustments of latex feed rate were made guided by the appearance of the concentrate passing through the glass inspection pipe. The objective was to maintain a minimum total solids content of 60% in the concentrate without exceeding the maximum viscosity at which the concentrate would freely flow down into the receiver. Samples of the latex concentrate were taken at frequent intervals. From the total solids contents of these, further minor adjustments in the rate of latex feed were made. With the equipment once operating at the desired conditions, it was seldom necessary to make any subsequent adjustments during a run.

At the conclusion of a run the start-up procedure was reversed. The jacket steam was first cut off, latex flow was then stopped, the evaporator agitator and condenser water were shut off, and the vacuum was broken to the atmosphere. Outage measurements gave the quantity of latex used out of the feed tank. The product and steam-jacket condensates and concentrated latex were collected and weighed.

### Experimental

#### INITIAL RUNS

The evaluation of the turbulent-film evaporator as a concentrator for GR-S latex had two objectives: first, to determine with latex the evaporating capacity and heat-transfer coefficient of this equipment, which were reported to be very high with other products; second, to appraise the adaptability of this equipment to the routine, day-after-day, commercial concentration of GR-S latices.

A series of short runs was made with the first objective in mind. Operating conditions and calculated capacities and heat-transfer coefficients for these runs appear in Table 1. In these runs the evaporator agitator, which was operated through a variable-speed drive, was run at several different speeds. Results show no effect on either heat-transfer coefficient or capacity resulting from a change in evaporator agitator speed. The variable-speed drive was then removed and in all subsequent runs the evaporator agitator was run at a speed of 800 rev./min.

From the data which were collected in the first eight runs the water evaporated in pounds per hour, or the evaporating capacity ($E$) was calculated thus:

$$E = 60\,R\,8.17\left(1 - \frac{S_1}{S_2}\right)$$

where

$E$ = lb. water evaporated/hr.
8.17 = lb./gal. GR-S latex
$R$ = latex flow in gal./min.
$S_1$ = % total solids in latex feed
$S_2$ = % total solids in latex concentrate

The heat-transfer coefficient ($U$) was calculated thus:

$$U = \frac{Q}{9\,\Delta T}$$

where

$Q = E \cdot h$
$\Delta T$ = steam-jacket temperature minus vapor temperature in ° F.
9 = total area of evaporating section in sq.ft.
$h$ = heat of vaporization of water at operating pressure in B.t.u./lb.

In the eight initial runs the evaporating capacity of the equipment was found to be about 400 lb./hr. The average heat-transfer coefficient was determined to be 288 B.t.u./(sq.ft.)(hr.)(° F.). It was found also that commercial GR-S latex could be continually concentrated from 40% to 60% total solids content in one pass through the turbulent-film evaporator.

The operation of the equipment during the early runs was not without difficulties. Particularly troublesome was a tendency for a film of rubber to build up on the polished shell of the evaporating section. Although not thick enough to have any noticeable effect on capacity and coefficient of heat transfer, this film

**Table 2.—Extended Run**

| Day | $S_1$ Latex Feed Total solids, % | $R$ Latex Feed Flow gal./min. | Latex Feed Temp., °F. | $S_2$ Concentrate Latex Total solids, % | Concentrate Latex Temp., °F. | Vacuum, mm. Hg abs. press. | Vapor Temp., °F. | Steam jacket press. lb./sq.in. gauge | Steam jacket temp., °F. | $E$ Water evaporated lb./hr. | Steam condensate lb./hr. | Steam efficiency lb. evaporated/lb. steam | $Q$ M B.t.u./hr. | $\Delta T$ | $U$ B.t.u./(hr.)(sq.ft.)(°F.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 40.6 | 1.86 | 77.4 | 59.5 | 98.6 | 50 | 100 | 5.7 | 229 | 290 | 323 | 0.90 | 302 | 129 | 260 |
| 2 | 41.3 | 1.92 | 78.6 | 61.1 | 95.7 | 50 | 100 | 5.3 | 228 | 304 | 321 | 0.95 | 316 | 128 | 275 |
| 3 | 39.8 | 1.97 | 80.9 | 60.6 | 96.3 | 46 | 98 | 4.0 | 224 | 331 | 335 | 0.99 | 344 | 126 | 303 |
| 4 | 39.5 | 1.91 | 81.6 | 61.0 | 97.5 | 47 | 98 | 4.0 | 224 | 329 | 353 | 0.93 | 342 | 126 | 301 |
| 5 | 40.3 | 1.88 | 82.3 | 61.3 | 108.9 | 64 | 109 | 5.6 | 229 | 317 | 354 | 0.90 | 330 | 120 | 305 |
| Average | 40.3 | 1.91 | 80.2 | 60.7 | 99.4 | 51 | 101 | 4.9 | 227 | 314 | 337 | 0.93 | 326 | 126 | 279 |

caused an overload on the agitator motor and eventually stopped the motor completely. This, in turn, resulted in a complete shutdown for cleaning. An increase in the horsepower of the agitator motor eliminated the overloading and permitted extended, uninterrupted runs.

In comparison with present-day latex concentration equipment, cleaning of the turbulent-film evaporator was quite simple. After the evaporating section was opened by removing both the bottom cone and the vapor head with the agitator, the tube was effectively cleaned by stripping out the thin rubber sleeve which had built up on the walls. Or, if the equipment were not opened, the tube was cleaned by running the agitator while a few gallons of a rubber solvent (carbon tetrachloride) were held in the evaporating section.

During the intial runs it was observed that variations in vacuum of more than a few millimeters caused an upset of equilibrium conditions and "priming" or "bumping." This resulted in carry-over of latex into the condenser and a sudden overloading of the agitator motor. The installation of an instrument which controlled the vacuum to within one millimeter of the desired setting eliminated this trouble.

Aside from these one or two instances, the condenser did not become fouled with latex and rubber. During steady operation there was no evidence of latex carry-over into the product condensate which indicated completely effective operation of the separating section.

## EXTENDED RUN

The second objective in the evaluation of the turbulent-film evaporator as a concentrator for GR-S latex was an appraisal of its adaptability to the continuous, routine concentration of commercial GR-S latex. A quantity of GR-S X-758 latex (a commercial latex widely used in the manufacture of foam sponge) at 40% total solids was obtained. This was continually concentrated to 60% total solids over a period of 5 consecutive days of 24 operating hours each. Actually because of tankage limitations, the same latex was used over and over during the 5-day extended run. The product condensate and latex concentrate were remixed and returned to the latex feed tank for reuse. The average operating conditions, evaporating capacities, heat-transfer coefficients, and steam efficiencies for the extended run are shown in Table 2.

In the 5-day extended run the average evaporating capacity and coefficient of heat transfer were found to be 314 lb./hr. and 279 B.t.u./(hr.)(sq.ft.)(°F.) respectively. An average of 0.93 lb. of water was evaporated/lb. of jacket steam used. The equipment was operated without interruption for 120 hr.

At the conclusion of the run the evaporator was opened for inspection. No rubber build-up was found on the polished heat-transfer surface, but there was a moderate amount of rubber on the bottom bearing support. The agitator and separating section were only slightly fouled. The vapor piping and condenser were clean. The appearance of the rubber deposits suggested that the build-up occurred, for the most part, during the early hours of the run. This is given confirmation by the uniformity of the daily performance figures shown in Table 2. There is no decrease in capacity, steam efficiency, or coefficient of heat transfer which would accompany a progressive fouling of the evaporator. It appears that the equipment could have been continually operated for many more days without cleaning.

The turbulent-film evaporator has been shown to be adaptable to the continual, once-through concentration of GR-S latex. The evaporating capacity of the unit evaluated was found to be, in the case of latex, equal to the manufacturer's design and to the reported capacities with other materials. The coefficient of heat transfer was high and characteristic of this equipment. Steam efficiency was good. The capital cost per unit of evaporated product for the turbulent-film evaporator is lower than for present-day GR-S latex concentrating installations, and cleaning and maintenance costs can also be expected to be lower.

**evaporation**

**Acknowledgment**

Thanks are due to F. A. Mauger of the Naugatuck synthetic rubber plant engineering department for supervision of the original installation and for many helpful suggestions offered during the course of the investigation, and to J. A. Reynolds for the photographic work.

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where $P_1$ is the pressure required to

both investigated an equation in which

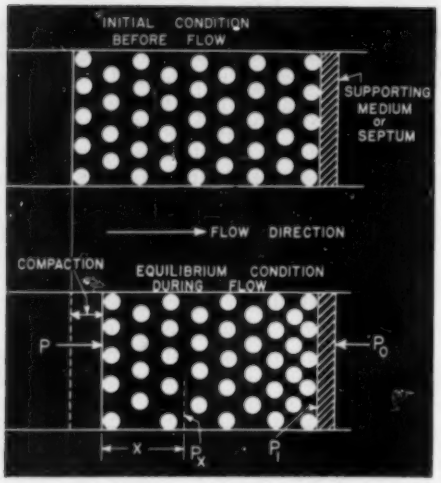
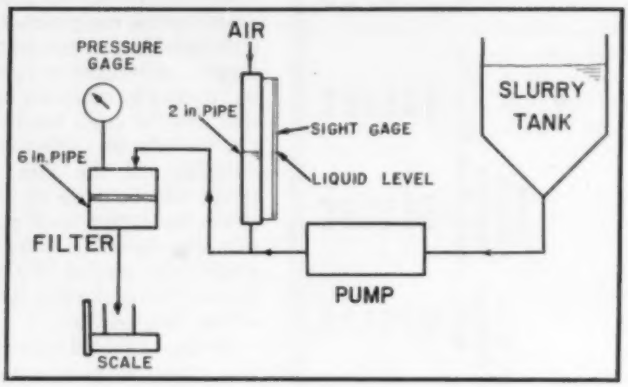



Fig. 3. Compaction within a solid during filtration.

Fig. 12. Schematic diagram of experimental apparatus.




# THE ROLE OF porosity in filtration

## PART 2 — Analytical Equations for Constant Rate Filtration

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In a previous paper (*10*) graphical procedures based on the Kozeny equation were developed for predicting pressure-volume-time relationships in constant pressure and constant rate filtration. Ingmanson (*5*) used essentially the same mathematical methods as were employed by the author in Part I (*10*) for treating data obtained in the constant pressure filtration of paper slurries. Both Ruth (*8*) and Grace (*4*) have indicated that the Kozeny equation in unmodified form is not adequate in general for the prediction of filtration resistance. For a wide variety of materials Grace showed that the specific filtration resistance increased more rapidly with pressure than could be accounted for with the simple Kozeny equation.

In this article analytical equations corresponding to the graphical methods of Part I are developed for constant rate filtration operations. Grace's experimental data are taken into account in modifying the Kozeny equation for application to the filtration formulas. The proposed analytical formulas are similar to empirical equations used by Coimbra (*3*) and Luke (*7*). The proposed equations are generally valid for the substances studied by Grace for pressures up to 100 lb. force/sq.in. except for the more highly compressible materials.

### Constant Rate Filtration Curves

Constant pressure filtration has long been favored in both university teaching and experimental investigations, presumably because of the simplicity of obtaining data. In constant pressure filtration the rate of filtration decreases as the cake builds up, and it is customary to obtain volume vs. time data. In constant rate filtration the volume is linear in time, and the variation of pressure $P$ with time $\theta$ is studied. In Figure 1 data for the constant rate filtration of two paper slurries (*12*) are exhibited. In the initial stages the pressure increased slowly, but after the pressure reached 15 lb. force/sq.in., the rate of buildup was much greater. In Figure 2 constant rate filtrations for a number of different laboratory investigations are illustrated. The curves are similar to those shown in Figure 1 except that the time is much shorter. In general, in a constant rate filtration, the initial linear pressure rise is followed by a curve of increasing upward curvature. With slightly compressible materials, this approximate linearity may extend over a considerable pressure range; while with highly compressible materials, there may be a large curvature in the pressure vs. time curve from the beginning of the filtration. The approximation of linearity in the pressure vs. time curves seldom may be extended above 20 lb. force/sq.in.

Most laboratory filtrations reported in the literature have been carried out at high rates of filtration, and consequently the time required to reach high pressures has been shorter than in typical industrial filtrations. In many cases the time of filtration has been less than 20 min., and in some experiments as little as 1 or 2 min. Both the author (*10*) and Lindquist and Youle(*6*) have pointed out that equilibrium cake conditions are not obtained instantaneously, and it is doubtful if a filtration carried out over a period of several minutes can be used for accurately predicting the results for longer filtrations. In general, experimenters should aim at lower rates and longer times of filtration.

### Empirical Constant Rate Equations

A number of equations have been proposed for representing the pressure vs. time relations in constant rate filtration. Ruth presented an equation for conditions of constant cake resistance of the form

$$P - P_1 = \frac{1}{g_c}\frac{s\rho\mu}{1 - ms}\,aq^2\theta \qquad (1)$$

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where $P_1$ is the pressure required to overcome the septum resistance, $s$ the per cent solids in the slurry, $\rho$ the liquid density, $\mu$ the liquid viscosity, $m$ the ratio of the mass of wet to dry cake, $\alpha$ the specific filtration resistance, $q$ the rate of filtration per unit area, and $g_c$ the conversion factor, poundals per pound force. Equation (1) demands that $P$ be linear in $\theta$ if $\alpha$ is constant. The curves of Figures 1 and 2 clearly indicate that the resistance increases with rising pressure, and consequently Equation (1) normally cannot be used if $\alpha$ is treated as a constant. Several empirical modifications of Equation (1) have been suggested by various authors.

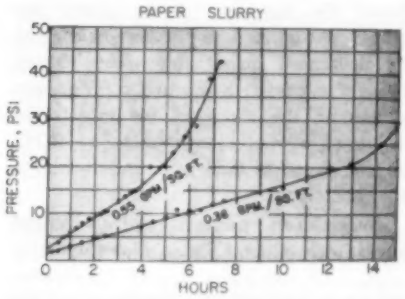


Fig. 1. Pressure vs. time for pilot plant constant rate filtration of paper slurries. Courtesy E. A. Ulrich, Process Filters, Inc.

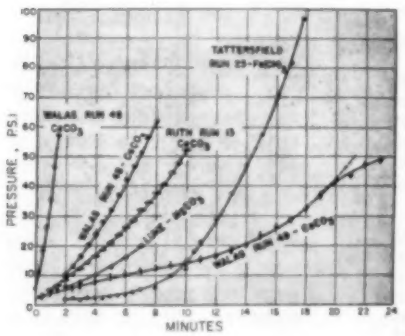


Fig. 2. Pressure vs. time for laboratory constant rate filtrations.

Ruth (*8*) and Coimbra (*3*) both suggested representing the specific resistance as a linear function of the pressure. Carman (*2*) proposed that the specific resistance be given as a power function of the pressure leading to

$$P - P_1 = P - \frac{1}{g_c}\mu R_m q$$

$$= \frac{1}{g_c}\frac{s\rho\mu}{1-ms} r P^n q^2\theta \qquad (2)$$

where $r$ is a constant and $R_m$ is the septum resistance. Coimbra (*3*) tested this equation using the data of Walas (*13*) and found that it worked reasonably well. Luke (*7*) and Coimbra (*3*) both investigated an equation in which the specific resistance was assumed to be a power function of the pressure drop $(P - P_1)$ across the cake. With this assumption, Equation (1) becomes

$$P - P_1 = \frac{1}{g_c}\frac{s\rho\mu}{1-ms} r(P-P_1)^n q^2\theta \qquad (3)$$

or

$$(P - P_1)^{1-n} = \frac{1}{g_c}\frac{s\rho\mu}{1-ms} r q^2\theta \qquad (4)$$

The Lewis (*14*) equation differs slightly from Equation (2) in that the septum resistance is also taken to vary as a power function of the pressure. The Lewis equation has been exhibited in the form

$$P - \mu\rho' P^{n_2} q = (r''v)\mu P^{n_1} q^2\theta \qquad (5)$$

If $n_2$ is taken as zero, Equation (5) reduces to Equation (2). Bonilla (*1*) indicated the difficulties of attempting to obtain the values of $n_1$ and $n_2$ from experimental data.

Semitheoretical formulas similar in form to these empirical equations will be derived in this paper. The conditions under which Equations (2) through (5) might be expected to be valid will be discussed. It will be demonstrated that with very compressible materials like polystyrene latex the power function approximation of the specific resistance is not valid over wide pressure ranges.

### Modified Kozeny Equation

In Figure 3 a picture of a filter cake with a precoat and supporting medium or septum is illustrated. As the liquid passes through the cake, the solids are compressed; and the filtration resistance increases, reaching a maximum at the interface with the precoat, if present, or otherwise with the supporting medium. The liquid or hydraulic pressure $P_x$ in lb. force/sq.ft. within the cake diminishes, and the net compressive pressure on the solids $P_s$ increases as the liquid passes through cake in accord with

$$P = P_x + P_s \qquad (6)$$

where $P$ is the applied filtration pressure (*2, 4, 5, 8, 10*).

According to the Kozeny equation (9), the rate of change of the liquid pressure $P_x$ with distance $x$ through the cake is given by

$$g_c\frac{dP_x}{dx} = -kS_o^2\frac{(1-\epsilon)^2}{\epsilon^3}\mu q \qquad (7)$$

where $g_c$ is the conversion factor from pounds force to poundals, $k$ a constant, $S_o$ the specific surface, $\epsilon$ the porosity, $\mu$ the viscosity, and $q$ the rate of filtration expressed as cu.ft./(sq.ft.)/(sec.).

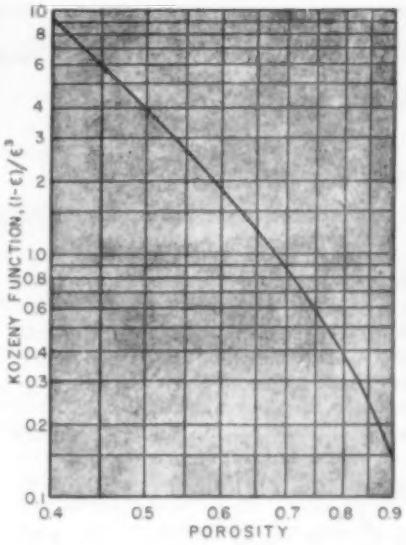


Fig. 4. Kozeny porosity function.

In experimental filtrations the mass of solids deposited is normally used instead of the distance term $x$, and it is usual to eliminate $x$ from Equation (7). If $w_s = W_s/A$ represents the mass of solids deposited per square foot in the distance from zero to $x$, then in thickness $dx$,

$$dw_s = \rho_s(1-\epsilon)dx \qquad (8)$$

where $\rho_s$ is the true solid density and $(1-\epsilon)dx$ is the true solid volume. Elimination of $dx$ from (7) leads to

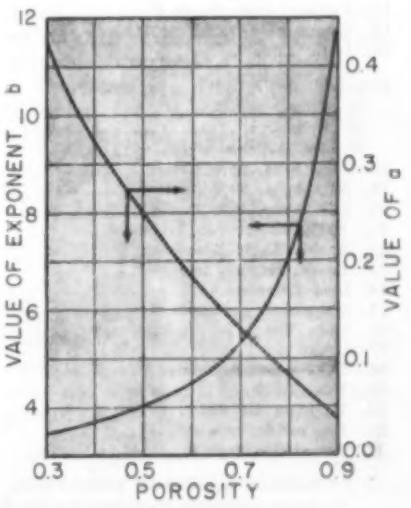


Fig. 5. Constants for power function approximations of Kozeny porosity function.

**Table 3**

| | | | | | | |
|---|---|---|---|---|---|---|
| $\theta_m$, min. | 5 | 10 | 20 | 30 | 40 | 47.9 |
| $p$, lb./sq.in., Eq. (29) | 6.0 | 14.4 | 33.9 | 56.2 | 79.8 | 100 |
| $p$, lb./sq.in., Graphical integration | 6.5 | 14.9 | 34.5 | 56.4 | 78.7 | 98.3 |

$$g_c \frac{dP_x}{dw_x} = -\frac{kS_o^2}{\rho_s} \frac{(1-\epsilon)}{\epsilon^3} \mu q \qquad (9)$$

Equation (9) can be modified to include the specific filtration resistance which is defined by

$$a_x = \frac{kS_o^2}{\rho_s} \frac{(1-\epsilon)}{\epsilon^3} \qquad (10)$$

Substituting (10) into (9) yields

$$g_c \frac{dP_x}{dw_x} = -a_x \mu q \qquad (11)$$

where $a_x$ represents the point value of the specific filtration resistance. The function $y = (1-\epsilon)/\epsilon^3$ is plotted logarithmically against $\epsilon$ in Figure 4. Over wide ranges of $\epsilon$, the curve in Figure 4 may be represented by a power function (10) of the form

$$y = \frac{1-\epsilon}{\epsilon^3} = a\epsilon^{-b} \qquad (12)$$

For example, in the region from 0.4 to 0.6 values may be assigned to the constants of $a = 0.243$ and $b = 4.00$. With these numerical values, the maximum error in $y$ amounts to approximately 2.5%. The average error over this region can be found from the integral.

$$\text{Average error} = \frac{1}{(0.6-0.4)} \int_{0.4}^{0.6} \frac{(1-\epsilon)/\epsilon^3 - 0.243\epsilon^{-4.0}}{(1-\epsilon)/\epsilon^3} d\epsilon \qquad (13)$$

$$= 1 - \frac{1}{0.2} \int_{0.4}^{0.6} \frac{0.243}{(1-\epsilon)} d\epsilon = 0.0149 \qquad (14)$$

Thus the average error over this relatively wide porosity range is less than 1.5%. As the porosity increases, the range over which the power function approximation is valid decreases.

In Figure 5 the values of $a$ and $b$ as found from tangents to the curve in Figure 4 are plotted against the porosity. To obtain values of $b$ for a given range of $\epsilon$, it is usually sufficiently accurate to find the exponent at an arithmetic average value of the porosity. Since the tangents all lie above the curve in Figure 4, the values of $a$ must be decreased below the values found from the curve in Figure 5. For example, in the range of 0.4 to 0.6 the value of $a$ was computed to be 0.243 as compared to 0.25 as found from the tangent.

Grace (*4*) experimentally showed that the product $kS_o^2$ in Equation (5)

**Table 1**

| Substance | Ref. | $\epsilon_o$ | $\sigma$ | Max. error in $\epsilon$ | Range, lb./sq.in. | $j(10^{-10})$ | $d$ | Range, lb./sq.in. |
|---|---|---|---|---|---|---|---|---|
| 1. Alumina | (4) | 0.875 | 0.0102 | 0.02 | 300 | 0.845 | 20.4 | 100 |
| 2. Aluminum oxide | (6) | 0.70 | 0.00 | 0.03 | 71* | 0.468** | 0 | 71* |
| 3. Asbestos | (10) | 0.91 | 0.017 | 0.008 | 100* | | | |
| 4. Calcium carbonate | (8) | 0.77 | 0.017 | 0.002 | 50* | 0.0565 | 5.35 | 50* |
| 5. Calcium carbonate | (13) | 0.55 | 0.036 | 0.005 | 50* | | | |
| 6. Superlight $CaCO_3$, dist. water | (4) | 0.78 | 0.033 | 0.01 | 200 | 11.1 | 3.52 | 1000 |
| 7. Superlight $CaCO_3$, $Na_4P_2O_7$ solution | (4) | 0.71 | 0.013 | 0.01 | 200 | 13.6 | 3.8 | 1000 |
| 8. Crushed limestone | (10) | 0.39 | 0.015 | 0.005 | 300 | | | |
| Carbon | | | | | | | | |
| 9. Norite A | (6) | 0.70 | 0.021 | 0.05 | 110* | 2.44** | 2.81 | 110* |
| 10. Suchar | (10) | 0.89 | 0.0091 | 0.002 | 100* | | | |
| 11. ⅓ Suchar ⅔ hyflo | (10) | 0.88 | 0.013 | 0.008 | 100* | | | |
| 12. Carbonyl iron, Grade E | (4) | 0.425 | 0 | 0.02 | 3000* | 0.758 | 0.49 | 3000 |
| 13. Copper oxide | (6) | 0.42 | 0.021 | 0.04 | 101* | 0.0201** | 5.24 | 101* |
| 14. Ferric oxide | (13) | 0.81 | 0.037 | 0.02 | 50* | | | |
| Filter aid | | | | | | | | |
| 15. Celite | (6) | 0.90 | 0.017 | 0.005 | 61* | 3.32** | 0 | 61* |
| 16. Hyflo | (10) | 0.88 | 0.014 | 0.01 | 100* | | | |
| 17. Std. Supercel | (4) | 0.875 | 0.0104 | 0.02 | 300 | 11.4 | 5.87 | 1000 |
| 18. 75% hyflo, 25% Kaolin | (10) | 0.84 | 0.020 | 0.02 | 100* | | | |
| 19. 50% hyflo, 50% Kaolin | (10) | 0.81 | 0.032 | 0.02 | 100* | | | |
| 20. 25% hyflo, 75% Kaolin | (10) | 0.68 | 0.044 | 0.018 | 100* | | | |
| 21. 100% Kaolin | (10) | 0.59 | 0.045 | 0.008 | 100* | 3.97 | 5.55 | 100* |
| 22. Kaolin, $Al_2(SO_4)_3$ solution | (4) | 0.585 | 0.049 | 0.02 | 200 | 418 | 0 | |
| 23. Kaolin, $Na_4P_2O_7$ solution | (4) | 0.60 | 0.031 | 0.025 | 200 | 35.8 | 1.54 | 1000 |
| 24. Lead Chromate | (6) | 0.78 | 0.036 | 0.015 | 101* | 0.801** | 5.56 | 101* |
| 25. Magnesium carbonate | (13) | 0.90 | 0.011 | 0.003 | 50* | | | |
| 26. Silica, fine | (4) | 0.975 | 0.006 | 0.005 | 200 | 707 | 61.6 | 200* |
| 27. Talc C | (4) | 0.86 | 0.054 | 0.02 | 100 | 39.6 | 3.11 | 1000 |
| 28. $TiO_2$, R-110, flocculated | (4) | 0.80 | 0.038 | 0.02 | 600 | 93.8 | 2.84 | 100 |
| 29. $TiO_2$, R-110 | (4) | 0.69 | 0.019 | 0.02 | 600 | 79.6 | 0 | 1000 |
| 30. Tungsten, UT 238 | (4) | 0.83 | 0.023 | 0.02 | 200 | 9.58 | 3.78 | 3000 |
| 31. Zinc sulfide, type A | (4) | 0.90 | 0.023 | 0.02 | 200* | 24.1 | 21.3 | 200* |
| 32. Zinc sulfide, type B | (4) | 0.90 | 0.047 | 0.01 | 200* | 621 | 11.2 | 200* |

* Maximum experimental pressure used.
** Values calculated from data for the flow of water through fixed beds of solids (*5*).
† Values taken from small graphs in Grace's paper (*4*) are approximate. Original data were not available.

may not be considered constant. In Figure 6 values of $kS_0^2$ as determined by Grace are plotted logarithmically against the porosity. One run reported by Ruth (*8*) for calcium carbonate is also included. For the twenty tests which Grace made, the three most compressible materials, Dow polystyrene latex, solka floc, and ilmenite, do not give straight line logarithmic plots of $kS_0^2$ vs. $\epsilon$. The curve for iron blue exhibited peculiarities with a rather sudden change in curvature and is not shown on the plots in Figure 6. For the straight portions of log $kS_0^2$ vs. log $\epsilon$, another power relation may be used to approximate the data as follows

$$kS_0^2 = j\epsilon^{-d} \qquad (15)$$

The values of $j$ and $d$ and the regions of validity of the equation are presented in Table 1. Substituting Equations (12) and (15) into (10) yields

$$\alpha_p = \frac{1}{\rho_s}(j\epsilon^{-d})(a\epsilon^{-b}) = \frac{aj}{\rho_s}\epsilon^{-(b+d)} \qquad (16)$$

From the experimental viewpoint the combined value of $(b+d)$ could be determined directly from the data without breaking the exponent into its separate components $b$ and $d$. It is interesting, however, to compute $d$ separately in order to study the deviation from Kozeny's equation.

The magnitude of the exponent $(b+d)$ can reach quite large values. With zinc sulfide, type *A*, as reported by Grace, the value of $d$ is 21.1 whereas $b$ is approximately 8.7, leading to a sum of 29.8. Such a large exponent makes it obvious that small changes in porosity can produce large changes in the specific filtration resistance. Substitution of Equation (16) into (11) produces

$$g_c \frac{dP_s}{dw_s} = -aj\epsilon^{-(b+d)}\frac{\mu}{\rho_s}q \qquad (17)$$

Before Equation (17) can be integrated analytically, it will be necessary to relate $\epsilon$ and $P_s$ to the compressive pressure $P_s$ on the solids.

#### Porosity-Compressive Pressure Relationship

In the first paper of this series porosity data of Lindquist and Youle (*6*), Ruth (*8*), Walas (*13*), and the author (*10*) were plotted logarithmically against the compressive pressure in the range up to 100 lb./sq.in. It was shown that the data could be approximated by a power function of the form.

$$\epsilon = \epsilon_0 p_s^{-e} \qquad (18)$$

where $p_s$ is the compressive pressure in lb. force/sq.in. and $\epsilon_0$ is the porosity at 1.0 lb. force/sq.in. If $P_s$ in lb. force/sq.ft. is substituted in (11), there results

$$\epsilon = \epsilon_0\left[\frac{p_s}{144}\right]^{-e} = E_0 p_s^{-e} \qquad (19)$$

where $E_0 = \epsilon_0(144)^e$.

Grace extended the range of compressive pressures to 3,000 lb. force/sq.in. in investigating the porosity characteristics of a number of substances. Some of his typical porosity data are plotted logarithmically in Figure 7 in the range up to 1,000 lb. force/sq.in. Except for the very compressible materials, like Dow polystyrene latex, solka floc (not plotted), and ilmenite (not plotted), the linear logarithmic relation is valid up to pressures ranging from 100 to 600 lb. force/sq.in. Since many filtrations are carried out below 100 to 200 lb. force/sq.in., the empirical relation presented in Equation (18) may be presumed to be of value as an approximation for moderately compressible solids. Values of $\epsilon_0$ and $e$ are given in Table 1 along with the values of $j$ and $d$.

As $p_s$ approaches zero in Equations (18) and (19), the calculated porosity approaches infinity, thus limiting the use of the expression at low pressures. A few of the available porosity data are plotted in the low pressure range in Figure 8 with both experimental and calculated values being shown. In general a relation such as Equation (18) could be used to some low pressure $p_i$, assumed to be 0.1 lb. force/sq.in. in this paper, with the porosity taken as constant below $p_i$. From a practical standpoint, the exact value of $p_i$ will not be of importance except for highly compressible materials.

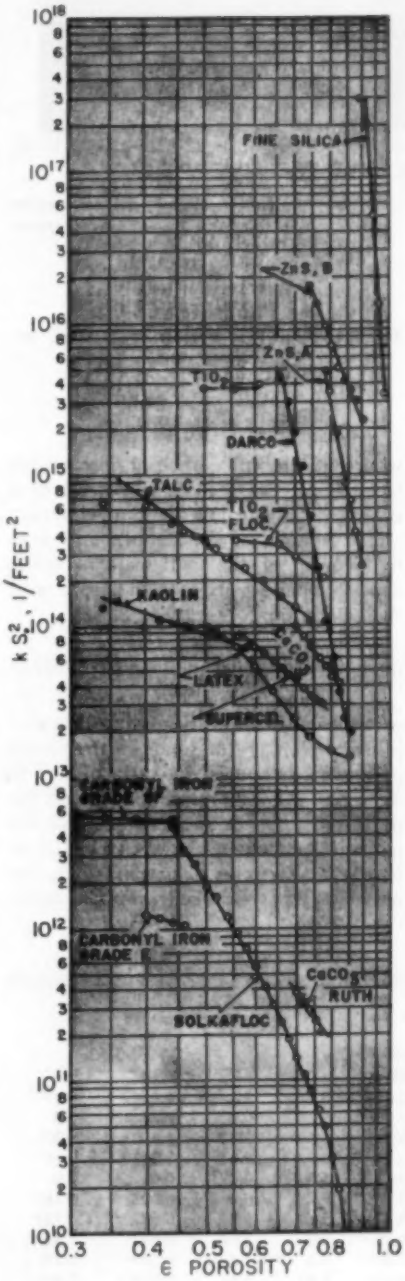


Fig. 6. $kS_0^2$ vs. $\epsilon$

The porosity can be eliminated from Equation (16) by means of Equation (19) to produce

$$\alpha_p = \frac{aj}{\rho_s}\epsilon_0^{-(b+d)}p_s^n$$

$$= \frac{aj}{\rho_s}\epsilon_0^{-(b+d)}(p - p_i)^n \qquad (20)$$

where $n = (b+d)e$ and $p_s = p - p_i$. Values for $b$, $d$, $e$, and $n$ as determined from data taken by Grace (*4*), Lindquist and Youle (*6*), and Ruth (*8*) are given in Table 2.

Below $p_i$ the value of the specific resistance may be considered constant and equal to $\alpha_i$, which is given by

$$\alpha_i = \frac{aj\epsilon_0^{-(b+d)}}{\rho_s}p_i^n \qquad (21)$$

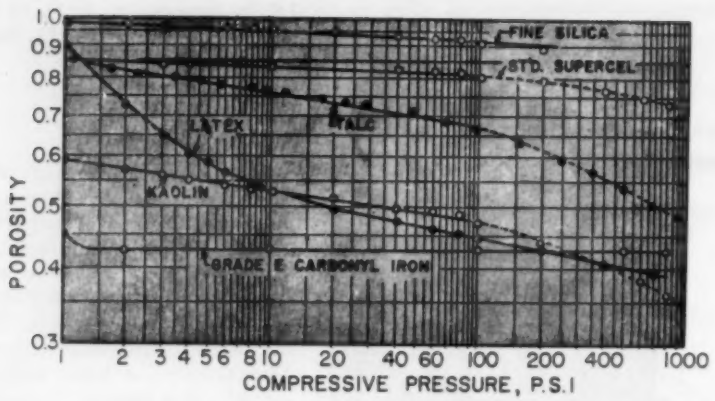


Fig. 7. Porosity vs. compressive pressure.

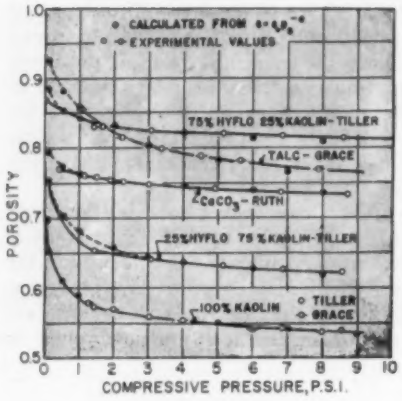


Fig. 8. Porosity vs. compressive pressure, low pressure range.

### Constant Rate Filtration Without a Precoat

In constant rate filtration the rate of filtrate flow is considered to be constant. Expressed mathematically

$$\frac{1}{A}\frac{dV}{d\theta} = \frac{dv}{d\theta} = q \qquad (22)$$

where $q$, the cubic foot of filtrate per square foot per second, is treated as a constant. It is convenient to eliminate $v$, the volume of filtrate per unit area in favor of $w$, the total mass of solids deposited per square foot, in accord with the relation

$$w = \frac{s\rho}{(1-ms)}\,v \qquad (23)$$

where $\rho$ is the density of the filtrate, $s$ is the percentage of solids in the slurry or prefilt, and $m$ is the ratio of wet to dry cake. As the pressure increases, the porosity of the cake decreases, and the moisture content decreases. Thus if $m$ is not constant in Equation (23), the mass of solids per square foot $w$ delivered to the press at any time will not be linear in the volume per square foot of filtrate $v$. The rate of flow of slurry and filtrate cannot both be constant unless the cake is noncompressible. Differentiating Equation (23) with respect to the time $\theta$ yields

$$\frac{dw}{d\theta} = \frac{s\rho}{(1-ms)}\frac{dv}{d\theta} + \frac{s^2\rho v}{(1-ms)^2}\frac{dm}{d\theta} \qquad (24)$$

Under most conditions the rate of change of $m$ with respect to $\theta$ will be small, and the last term can be neglected. If in addition the slurry is relatively dilute and $(1-ms)$ does not change greatly, both $dw/d\theta$ and $dv/d\theta$ may be constant simultaneously. Substitution of $v = q\theta$ in Equation (23) gives

$$w = \frac{s\rho}{1-ms}\,q\theta \qquad (25)$$

Equation (25) gives the mass of dry solids deposited as a function of the time.

In order to relate the pressure to the time, the mass of dry solids $w$ must be obtained from Equations (11), (20), and (21) by integrating $dw_x$. Rearranging Equation (11) and integrating yields

$$\int_0^w dw_x = w = \frac{s\rho}{1-ms}\,q\theta$$

$$= -\frac{g_c}{\mu q}\int_P^{P_1}\frac{dP_x}{a_x} \qquad (26)$$

In determining the lower limit of integration, one should note that at the surface of the filter cake the deposited solids $w_x$ are zero whereas the liquid pressure $P_x$ equals the applied filtration pressure $P$. Equation (26) may be rearranged to give

$$\frac{1}{g_c}\frac{s\rho\mu}{1-ms}\,q^2\theta = \int_{P_1}^{P}\frac{dP_x}{a_x} \qquad (27)$$

The upper limit $P$ of the integral represents the variable filtration pressure which is a function of $\theta$.

Substituting for $a_x$ as given by Equation (20) and changing to lb. force/sq.in. leads to

$$\frac{1}{g_c}\frac{s\rho\mu}{1-ms}\,q^2\theta$$

$$= \frac{p_s\epsilon_0^{\,(b+4)}}{aj}\int_{p_1}^{p}(p-p_x)^{-n}(144\,dp_x) \qquad (28)$$

**Table 2**

| Substance | Ref. | Porosity range | b | d | e | n |
|---|---|---|---|---|---|---|
| 1. Alumina | (4) | 0.80–0.88 | 8.3 | 20.4 | 0.0102 | 0.29 |
| 2. Aluminum oxide | (8) | 0.65–0.70 | 5.26 | 0.0 | 0.0 | 0.0 |
| 3. Superlight $CaCO_3$, dist. $H_2O$ | (4) | 0.67–0.78 | 5.6 | 3.52 | 0.022 | 0.20 |
| 4. $CaCO_3$ | (6) | 0.70–0.77 | 5.7 | 5.35 | 0.017 | 0.19 |
| 5. Carbonyl iron | (4) | 0.41–0.43 | 3.7 | 0.49 | 0.0 | 0.0 |
| 6. Celite | (6) | 0.84–0.87 | 9.7 | 0.0 | 0.005 | 0.139 |
| 7. Copper oxide | (6) | 0.39–0.41 | 3.68 | 5.24 | 0.04 | 0.187 |
| 8. Darco | (4) | 0.74–0.85 | 6.9 | 21.6 | 0.017 | 0.48 |
| 9. Kaolin, $Al_2(SO_4)_3$ solution | (4) | 0.45–0.59 | 4.0 | 1.54 | 0.049 | 0.28 |
| 10. Lead Chromate | (6) | 0.64–0.71 | 5.54 | 5.56 | 0.015 | 0.399 |
| 11. Norite | (6) | 0.66–0.70 | 5.20 | 2.81 | 0.05 | 0.17 |
| 12. Fine silica | (4) | 0.90–0.98 | 25 * | 1.6 | 0.0155 | 1.34* |
| 13. Std. supercel | (4) | 0.77–0.85 | 7.3 | 5.87 | 0.0104 | 0.137 |
| 14. Talc C | (4) | 0.66–0.86 | 6.26 | 3.11 | 0.054 | 0.506 |
| 15. R-110 $TiO_2$, flocculated | (4) | 0.52–0.62 | 4.3 | 2.84 | 0.038 | 0.27 |
| 16. UT 238 Tungsten | (4) | 0.72–0.81 | 6.2 | 3.78 | 0.0165 | 0.163 |
| 17. Zinc sulfide, type A | (4) | 0.78–0.90 | 8.3 | 21.3 | 0.023 | 0.68** |
| 18. Zinc sulfide, type B | (4) | 0.69–0.90 | 6.9 | 11.2 | 0.047 | 0.85 |

* Rough value due to rapid rate of change with porosity.
** Grace's data are curved for ZnS, type A. The value 0.68 is an average.

The integration must be performed in two parts since $\alpha_x$ is assumed constant below $p_s = p - p_x = p_i$. While the liquid pressure $p_x$ is falling from the applied pressure $p$ to $(p - p_i)$, the porosity remains essentially constant, and $\alpha_x$ is given by (21). As preparation for the integration there results

$$\frac{1}{g_c}\frac{s\rho\mu}{1-ms}\,q^2\theta = \frac{144\rho_s\epsilon_0^{b+d}}{aj}\left[\int_{p_1}^{p-p_i}(p-p_x)^{-n}dp_x + \int_{p-p_i}^{p} p_i^{-n}dp_x\right] \quad (29)$$

By integrating

$$\frac{1}{g_c}\frac{s\rho\mu}{1-ms}\,q^2\theta = \frac{144\rho_s\epsilon_0^{b+d}}{aj}\left[p_i^{(1-n)} + \frac{(p-p_1)^{1-n} - p_i^{1-n}}{1-n}\right] \quad (30)$$

provided $n$ is not equal to unity and $(p - p_1)$ is greater than $p_i$. Algebraic manipulation of Equation (30) produces

$$(p-p_1)^{1-n} - np_i^{(1-n)} = \frac{1}{g_c}\left(\frac{s\rho\mu}{1-ms}\right)(1-n)\,\frac{aj}{144\rho_s\epsilon_0^{(b+d)}}\,q^2\theta \quad (31)$$

This result is similar to Equation (4), which was proposed empirically by Luke (7) and Coimbra (3). As the filtration progresses, $(p - p_1)^{1-n}$ will increase if $n$ is less than unity, and the constant $np_i^{1-n}$ will become smaller in relation to $(p - p_1)^{1-n}$. If $p_i$ is taken as 0.1 lb. force/sq.in. and $n$ is not greater than 0.5, the value of $np_i^{1-n}$ will be only 5% of $(p - p_1)^{1-n}$ by the time the latter term has reached 10 lb. force/sq.in. If $n$ is as large as 0.7, the term $np_i^{1-n}$ cannot be neglected at pressures below 100 lb. force/sq.in.

In order to compute the average specific filtration resistance, it is essential to place Equation (31) in a form corresponding to Equation (1). Thus

$$P - P_1 = 144(p-p_1) = \frac{1}{g_c}\frac{s\rho\mu}{1-ms}\,(1-n)\,\frac{aj}{\rho_s\epsilon_0^{(b+d)}}\,\frac{(p-p_1)^n}{\left[1-n\left(\frac{p_i}{p-p_1}\right)^{1-n}\right]}\,q^2\theta \quad (32)$$

Solving for $\alpha$ in this equation yields

$$\alpha = (1-n)\,\frac{aj}{\rho_s\epsilon_0^{b+d}}\left[\frac{(p-p_1)^n}{1-n\left(\frac{p_i}{p-p_1}\right)^{1-n}}\right] \quad (33a)$$

or approximately when $n$ is not too large

$$\alpha = (1-n)\,\frac{aj}{\rho_s\epsilon_0^{(b+d)}}\,(p-p_1)^n \quad (33b)$$

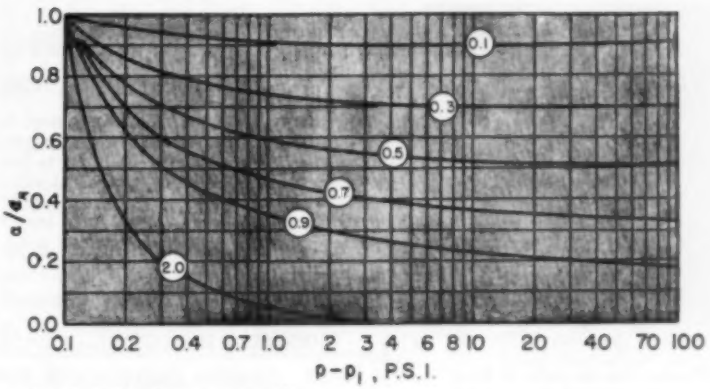


Fig. 9. Ratio of average specific resistance to point value.

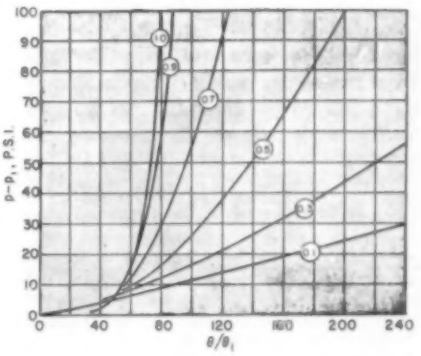


Fig. 10. Pressure rise vs. ratio of filtration time to time required to reach 0.1 lb. force/sq.in.

These equations are valid for $(p - p_1)$ greater than $p_i$. When $(p - p_1)$ is less than $p_i$, the specific resistance and porosity are both assumed constant in accord with Equation (21). Integration of Equation (28) when $(p - p_1)$ is less than $p_i$ produces

$$P - P_1 = 144(p-p_1) = \frac{1}{g_c}\frac{s\rho\mu}{(1-ms)}\frac{aj}{\rho_s}\,\epsilon_0^{-(b+d)}p_i^n q^2\theta \quad (34)$$

The ratio of the average specific resistance from (33a) to the value given in (20) is of interest.

$$\frac{\alpha}{\alpha_x} = \frac{1-n}{1-n\left[\frac{p_i}{p-p_1}\right]^{1-n}} \quad (35)$$

If $p_i$ is taken as 0.1 lb. force/sq.in., the ratio $\alpha/\alpha_x$ is plotted against $(p - p_1)$ for various values of $n$ in Figure 9. Above an $n$ of 0.5 – 0.7 the approximations used in deriving Equation (35) lose accuracy; and consequently the curves for $n$ ranging from 0.7 to 2.0 have only semiquantitative value. For $n = 2.0$ the ratio $\alpha/\alpha_x$ approaches zero as $(p - p_1)$ becomes larger, and it might appear that $\alpha$ was becoming small. However, when $n > 1$, the value of $\alpha_x$ increases more rapidly than the value of $\alpha$, and the ratio $\alpha/\alpha_x$ becomes smaller.

Interesting information concerning the pressure vs. time curves can be drawn from a combination of Equations (31) and (34). The time $\theta_i$ required to reach a pressure drop across the cake of $\Delta p_c = p - p_1 = p_i$ can be obtained from Equation (34). The ratio of the time $\theta$ [Equation (31)] to $\theta_i$ is given by

$$\frac{\theta}{\theta_i} = \frac{\Delta p_c^{1-n} - np_i^{1-n}}{(1-n)p_i} \quad (36)$$

Plots of $\Delta p_c$ vs. $\theta/\theta_i$ at constant values of $n$ are illustrated in Figures 10 and 11. The curves of Figure 10 are similar to those previously shown in Figures 1 and 2. For $n < 0.1$, a straight line may be used to approximate the data over a considerable pressure range. When $n$ increases to 0.3, it is difficult to represent the pressure vs. time as a linear

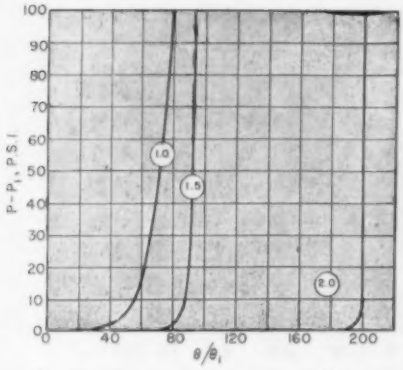


**Fig. 11. Pressure rise vs. ratio of filtration time to time required to reach 0.1 lb. force/sq.in.**

function beyond 5 to 10 lb./sq.in. When $n$ reaches values near 0.7, the curves are characterized by an initial flat portion of the curve followed by a rapidly increasing slope.

For $n$ greater than unity Equation (36) is best placed in the form

$$\frac{\theta}{\theta_i} = \frac{1}{(n-1)p_i}\left[\frac{n}{p_i^{(n-1)}} - \frac{1}{\Delta p_c^{(n-1)}}\right] \quad (37)$$

A plot of $\Delta p_c$ vs. $\theta/\theta_i$ for $n > 1.0$ is shown in Figure 11. The curves, although qualitative in nature, indicate an asymptotic approach to infinite pressure at a finite time. In Equation (37), as $\Delta p_c$ approaches infinity, the last term becomes zero, and the ratio of $\theta/\theta_i$ is given by

$$\frac{\theta}{\theta_i} = \frac{n}{n-1} p_i^{-n} \quad (38)$$

For example, if $n = 2.0$, $\theta/\theta_i = 200$ in Equation (38), indicating that when the time reaches two hundred times the value required to reach 0.1 lb. force/sq.in., the pressure will rise asymptotically to a very large value. Again it should be emphasized that the calculations are only approximate for $n$ greater than 0.7.

Example 1: In a previous paper (*10*), the author presented several examples based upon the graphical integration of the fundamental equations. To compare the exact graphical procedure with the equations developed in this paper, Example 2 of Part I will be worked by use of the proposed analytical equations.

A solid is to be filtered in a unit with a negligible septum resistance at a constant rate of 0.5 gal./(min.)(sq.ft.). It is desired to calculate pressure vs. time up to pressures of 100 lb. force/sq.in. The slurry is dilute and contains 0.5% solids by weight. Other necessary information is as follows:

$\mu = 1$ centipoise
$\rho = 62.4$ lb. mass/cu.ft.
$\rho_s = 124.8$ lb. mass/cu.ft.
$S_s = 2{,}000{,}000$ sq.ft./cu.ft.
$\theta_m$ = min. $= \theta/60$

The porosity is related to the pressure by

$$\epsilon = 0.59\ p_s^{-0.045} \quad (39)$$

Since Kozeny's equation was assumed to apply in the example of the previous paper, the value of $d$ will be zero. In order to use Equation (32), it is necessary to calculate the values of $a$ and $b$ from Equation (12) based upon the range in $\epsilon$. As 100 lb. force/sq.in. is the maximum pressure, the minimum value of $\epsilon$ as calculated from Equation (39) is 0.479. For this range of porosity (0.479 to 0.59) the values of $a = 0.213$ and $b = 4.23$ can be used.

Changing the rate from gal./min. to consistent units yields a value of 0.00113 cu.ft./(sec.)(sq.ft.). The factor $j$ will be simply $kS_s^n = 2(10)^{12}$ since the specific surface is assumed constant and $d$ is zero. The exponent $n$, given by the product of $b$ times $e$, is $n = (0.045)(4.23) = 0.19$. Since the medium resistance is negligible, $P_1 = 0$. Substituting the appropriate values in Equation (32), assuming $(1 - ms)$ to be unity, and $p_i$ to be 0.1 lb. force/sq.ft., yields

$$p = \frac{(0.005)(62.4)(0.000672)(1-0.19)(0.213)(5)(4)(10)^{12}(0.00113)^2(60)p^{0.19}}{(144)(32.2)(124.8)(0.59)^{4.23}\left[1 - 0.19\left(\frac{0.1}{p}\right)^{1-0.19}\right]}\theta_m \quad (40)$$

where $\theta_m$ is the time in minutes. The term $[1 - 0.19(0.1/p)^{0.81}]$ is virtually unity for $p$ greater than 5 lb./sq.in. Therefore the expression may be simplified to

$$p^{0.81} = 0.868\theta_m \quad (41)$$

In Table 3 the values computed by the exact graphical method are shown to compare favorably with the values found from Equation (41).

Example 2. The previous example was concerned with the filtration of a material which followed Kozeny's law. To deal with a material which deviates from the Kozeny equation, talc is considered to have the properties listed by Grace (*4*). If the filtration is performed under the following conditions, and the pressure is to be calculated vs. the time,

| | |
|---|---|
| Percentage of solids in slurry | $s = 0.01$ |
| Liquid density | $\rho = 62.4$ lb. mass/cu.ft. |
| Viscosity | $\mu = 0.001$ lb. mass/(ft.)(sec.) |
| Density of talc | $\rho_s = 167$ lb. mass/cu.ft. |
| Rate of filtration | $q = 0.000362$ cu.ft./(sec.)(sq.ft.) |
| Initial pressure | $p_i = 2.0$ lb./sq.in. |

The values of the parameters necessary for solving the problem as found in Tables 1 and 2 are

| | |
|---|---|
| $\epsilon_s = 0.86$ | $j = 39.6(10^{12})$ |
| $\epsilon = 0.054$ | $d = 3.11$ |

For the porosity range of 0.67 to 0.86 the values of $a = 0.0934$ and $b = 6.26$ may be employed. Calculations of $n$ yields $n = (3.11 + 6.26)(0.054) = 0.506$.

Since the slurry is not so dilute as in Example 1, it will be necessary to check on the variation of $(1 - ms)$, which was assumed constant in the derivations. The value of $m$ is given by

$$m = \frac{\text{Mass of wet cake}}{\text{Mass of dry cake}}$$

$$= 1 + \frac{\text{Mass of water}}{\text{Mass of dry cake}} \quad (42)$$

On the basis of 1 cu.ft., Equation (42) becomes

$$m = 1 + \frac{\epsilon}{1-\epsilon}\frac{\rho}{\rho_s} \quad (42)a$$

Calculating the values of $m$ and $1 - ms$ yields

| Pressure | 1.0 lb. force/sq.in. | 100 lb. force/sq.in. |
|---|---|---|
| $m$ ..... | 3.30 | 1.76 |
| $1 - ms$ ..... | 0.967 | 0.982 |

In spite of the relatively wide variation in the moisture content of the cake, the variation in $(1 - ms)$ is small. At 100 lb. force/sq.in. the value of $m$ will range from 1.76 at the densest part of the cake near the septum to a value larger than 3.30 at the surface of the cake. An average value of 0.974 for $(1 - ms)$ will be used in this example.

The time required to reach a given pressure can be obtained from Equation (31), thus

$$(p-2)^{0.494} - 0.506(0.1)^{0.494} = \frac{(0.01)(62.4)(0.001)(0.494)(0.0934)(39.6)(10^{12})(3.62)^2(10^{-6})(60)}{(32.2)(0.974)(144)(167)(0.86)^{0.97}}\theta_m = 0.0489\theta_m \quad (44)$$

where $\theta_m$ is the time in minutes. Based upon Equation (44), the pressure vs. time calculations yield

| $p$, lb./sq.in. | 2 | 10 | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|---|---|
| $\theta_m$, min. | 0 | 54 | 82 | 120 | 149 | 174 | 184 |

**Constant Rate Filtration With a Precoat**

When a precoat is used in filtration, the liquid must pass through two solids in series. The filtration problem is analogous to the situation in heat transfer in which heat is transferred through two resistances in series. As the rate of flow of filtrate is the same through the two solids, it is convenient to solve for $q$ in Equation (11). Mathematically the basic equations for flow through two solids (see Figure 3) and a filter medium are

$$q = -\frac{1}{\mu a_x} g_c \frac{dP_x}{dw_x} = -\frac{1}{\mu a_{x1}} g_c \frac{dP_{x1}}{dw_{x1}}$$

$$= \frac{1}{\mu R_m} g_c (P_1 - P_o) \qquad (45)$$

where $P_o$ is the back pressure, which is usually considered to be zero, and subscript 1 is used to denote the precoat. Integration of (45) is carried out in a manner similar to the procedure used with Equation (26). Thus for the cake there results

$$\frac{1}{g_c} \frac{s\rho\mu}{1 - ms} q^2\theta = \int_{P_2}^{P} \frac{dP_x}{a_x} \qquad (46)$$

where $P_2$ is the pressure at the interface between the cake and precoat. For the precoat

$$\mu q \int_o^{w_1} dw_{x1} = \mu q w_1$$

$$= \int_{P_1}^{P_2} \frac{dP_{x1}}{a_{x1}} \qquad (47)$$

where $P_1$ is the pressure between the precoat and the septum. The quantity $w_1$ represents the constant value of the mass of precoat per square foot. Integration of Equation (46) produces a form which is identical with Equation (31), thus

$$(p - p_2)^{(1-n)} - np_i^{(1-n)}$$

$$= \frac{1}{g_c} \frac{s\rho\mu}{1 - ms} (1 - n) \frac{aj}{144\, \rho_s \epsilon_o^{(b+d)}} q^2\theta \qquad (48)$$

Since $p_2$ is an unknown value in this equation, it must be found from Equation (47). To integrate (47), $a_{x1}$ must be related to the compressive pressure $p_s$ by Equation (20). The differential $dP_{x1}$ is replaced by $-dP_{s1}$, and limits of integration are changed in accord with Equation (6). When $p_{s1} = p_1$, the value of $p_{s1} = p - p_1$; and when $p_{s1} = p_2$, the value of $p_{s1} = p - p_2$. Equation (49) becomes

$$\mu q w_1 = \frac{(144)\rho_{s1}\epsilon_{o1}^{(b_1+d_1)}}{a_1 j_1} \int_{p-p_2}^{p-p_1} p_{s1}^{-n_1} dp_{s1} \qquad (49)$$

As a satisfactory approximation, the porosity or $p_{s1}$ may be considered constant throughout the precoat. If $p_1$ and $p_2$ are small as they normally will be, the pressures $(p - p_1)$ and $(p - p_2)$ will not be greatly different. Since $p_1$ is known, $p_s$ may be assumed constant and equal to $(p - p_1)$ in the integration which yields

$$\mu q w_1 = \frac{144\rho_{s1}\epsilon_{o1}^{(b_1+d_1)}}{a_1 j_1} (p - p_1)^{-n_1}(p_2 - p_1) \qquad (50)$$

Solving for $p_2$ in Equation (50) so that the results may be substituted in Equation (48) yields

$$p_2 = p_1 + \frac{a_1 j_1 \mu q w_1}{144\rho_{s1}\epsilon_{o1}^{(b_1+d_1)}} (p - p_1)^{n_1} \qquad (51)$$

Substituting in Equation (48) leads to

$$(p - p_1)^{1-n} \left[1 - \frac{a_1 j_1 \mu q w_1}{144\rho_{s1}\epsilon_{o1}^{(b_1+d_1)}} \frac{1}{(p - p_1)^{1-n_1}}\right]^{1-n} - np_i^{(1-n)}$$

$$= \frac{1}{g_c} \frac{s\rho\mu}{1 - ms} (1 - n) \frac{1}{144\rho_s\epsilon_o^{(b+d)}} q^2\theta \qquad (52)$$

which represents the desired equation for the $p$ vs. $\theta$ relationship.

Equation (52) can be modified into a form which is similar to the Lewis equation. If $n$ is 0.5 or less, the term $np_i^{1-n}$ can be neglected after the pressure has reached 10 lb. force/sq.in. If $p_1$ is zero, the value of $p_2$ is given by

$$p_2 = \frac{a_1 j_1 \mu q w_1}{144\rho_{s1}\epsilon_{o1}^{(b_1+d_1)}} p^{n_1} \qquad (53)$$

Combining (52) with (48) after $np_i^{1-n}$ has been eliminated yields

$$p - \frac{a_1 j_1 w_1}{144\rho_{s1}\epsilon_{o1}^{(b_1+d_1)}} \mu q p^{n_1} = \frac{1}{g_c} \frac{s\rho\mu}{1 - ms} \frac{(1 - n)aj}{144\rho_s\epsilon_o^{(b+d)}} (p - p_1)^n q^2\theta \qquad (54)$$

Equation (54) differs from the Lewis equation in that $(p - p_1)^n$ rather than $p^n$ appears on the right-hand side.

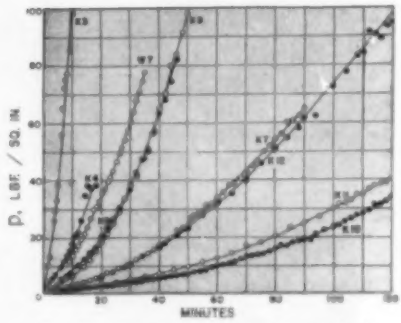


Fig. 13. Pressure vs. time for constant rate filtration of kaolin.

**Experimental Data**

A number of constant rate runs were made with aqueous slurries of kaolin. The percentage of solids was varied from 0.002% to 1.0%, and the rate of filtration ranged from 2—11 cu.ft./(hr.)(sq.ft.). Final pressures ranging from 30 to 100 lb. force/sq.in. were recorded with the total filtration time ranging from 10 min. to 2 hr. The longer filtration times were chosen in order to avoid the difficulties encountered by other investigators of constant rate filtration.

A schematic drawing of the experimental apparatus is shown in Figure 12. The slurry was fed to a Milton-Roy positive displacement, adjustable stroke pump operating at 100 cycles/min. A 2-in. pipe with an air chamber was placed at the outlet of the pump in order to dampen the pressure surges due to the slow speed of operation. As the pressure on the filter cake increased, the liquid level in the pipe was maintained constant by admitting compressed air. The rate of filtration would have varied if the pump had delivered part of its output to 2-in. pipe and the liquid level had been permitted to rise. The rate of filtration was kept within approximately ±3% of the average rate. There was a tendency for the rate to decrease slightly when the pressure exceeded 10 lb. force/sq.in. Fresh kaolin was used in each run. Pressures were recorded both with manometers and Bourdon gauges.

In Figure 13 the pressure vs. time data for a few of the runs are plotted. In general it was possible to obtain reasonable checks on the data, except when the time required to reach 100 lb. force/sq.in. was less than 10—15 min. The data were rectified by plotting log $(p-p_1)$ vs. log $\theta$ as indicated in Figure 14. Because of the difficulty of obtaining $p_i$ (ranging from 0.1 to 0.5 lb. force/sq.in.) and the initial time exactly, the logarithmic plots are not too reliable in the region below 10 lb. force/sq.in. and 10 min. When the log $(p-p_1)$ vs. log $\theta$ plot is used, the term $np_i^{(1-n)}$ in Equation (31) is neglected when a straight line is drawn. Inclusion of the $np_i^{(1-n)}$ term would yield a negative correction to the pressure which might be significant at low pressures. In the low pressure range all the data lie above the straight line, thereby indicating that a negative correction would bring the points closer to the line predicted by the theory.

filtration

$\theta_m$ = min. = $\theta/60$



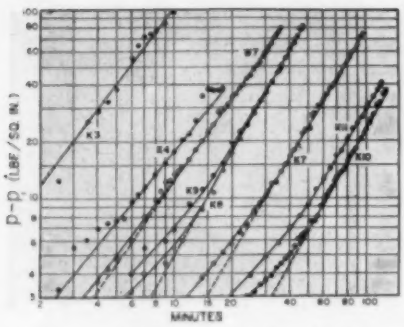


Fig. 14. Logarithmic plot of data from Figure 13.

The values of $n$ as obtained from Figure 14 are plotted against the time required to reach 10 lb. force/sq.in. in Figure 15. Below times of 15 min. the value of $n$ decreases below the limiting value of 0.44. At the high rates and short times, it is probable that the cake does not have sufficient time to consolidate; and consequently, the porosity does not change as much from its initial value as it does at lower filtration rates. In the limiting case of an infinite filtration rate and infinite rate of pressure rise, it is possible that the cake would compress very little and the value of $n$ would approach zero. In Figure 15 a dotted line is shown passing through the origin in accord with the thesis that the consolidation is lessened at high rates. The data are difficult to obtain in the region below 10 min. on Figure 14, and precise values of $n$ could not be obtained. With a value of $n = 0.44$, $b = 4.2$, and $e = 0.045$, a value of $d = 5.55$ may be calculated. This value of $d$ indicates that the solid deviated markedly from the predictions of the simple Kozeny equation.

The data of Figures 13 through 15 can be represented by the equation

$$(p - p_1)^{0.56} = 6.98(10^9)s\mu q^2\theta \qquad (55)$$

where the slurry is dilute and the pressure difference is above approximately 8.0 lb. force/sq.in. Combining Equation (55) with Equation (32) permits the calculation of $j$, which is found to be $3.97(10^{28})$.

The difficulty of obtaining data in the region of high rates of filtration may account for some of the discrepancies which have been found in the literature. Most experimental constant pressure and constant rate filtrations have been conducted over short time increments in the region where the compressibility coefficient is a function of the rate of filtration as well as the pressure. In the performance of scale-up experiments every attempt should be made to have a relatively long filtration. With high rates the value of $a$ may be lower than at low rates and erroneous calculation of filter areas may result.

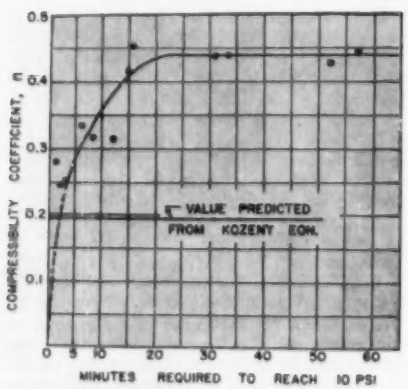


Fig. 15. Variation of compressibility coefficient.

**Acknowledgment**

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**Notation**

$A$ = filter area, sq.ft.
$a$ = constant defined by Equation (12)
$a_1$ = value of $a$ for precoat
$b$ = constant defined by Equation (12)
$b_1$ = value of $b$ for precoat
$d$ = constant defined by Equation (15)
$d_1$ = value of $d$ for precoat
$e$ = constant defined by Equation (18)
$E_o$ = constant defined by Equation (19)
$g_c$ = conversion factor, poundals/lb. force or (lb. mass)(ft.)/(lb. force)(sec.$^2$)
$j$ = constant defined by Equation (15)
$j_1$ = value of $j$ for precoat
$k$ = Kozeny constant, Equation (7)
$m$ = ratio of mass of wet to dry cake
$n$ = compressibility coefficient, Equation (20)
$n_1$ = value of $n$ for precoat
$n_1, n_2$ = constants in Lewis Equation (5)
$P$ = applied filtration pressure lb. force/sq.ft.
$p$ = applied filtration pressure lb. force/sq.in.
$p_1$ = low pressure below which porosity is constant lb. force/sq.in.
$P_s$ = solid compressive pressure, lb. force/sq.ft.
$p_s$ = solid compressive pressure, lb. force/sq.in.
$p_{s1}$ = solid compressive pressure in precoat, lb. force/sq.in.
$P_x$ = liquid pressure at $x$ ft. from surface, lb. force/sq.ft.
$p_x$ = liquid pressure at $x$ ft. from surface, lb. force/sq.in.
$P_{s1}$ = pressure in precoat, lb. force/sq.ft.
$p_{s1}$ = pressure in precoat, lb. force/sq.in.
$P_1$ = pressure at interface of septum or precoat and cake, lb. force/sq.ft.
$p_1$ = pressure at interface of septum or precoat and cake, lb. force/sq.in.
$P_2$ = pressure at interface of cake and precoat lb. force/sq.ft.
$p_2$ = pressure at interface of cake and precoat lb. force/sq.in.
$P_o$ = back pressure on filter, lb. force/sq.ft.
$p_o$ = back pressure on filter, lb. force/sq.in.
$\Delta P_c$ = pressure drop across cake, lb. force/sq.ft.
$\Delta p_c$ = pressure drop across cake, lb. force/sq.in.
$r$ = constant in Coimbra's Equation (3)
$r''v$ = constant in Lewis Equation (5)
$R_m$ = medium resistance, 1/ft.
$s$ = percentage of solids in slurry
$S_o$ = specific surface, sq.ft./cu.ft. of solid
$x$ = distance from filter cake surface, ft.
$y$ = Kozeny function, $\epsilon/(1-\epsilon)^3$
$w$ = mass of filter cake per unit area, lb. mass/sq.ft.
$w_1$ = mass of precoat per unit area lb. mass/sq.ft.
$w_x$ = mass of filter cake per unit area deposited in first $x$ ft., lb. mass/sq.ft.
$\alpha$ = average specific filtration resistance, ft./lb. mass
$\alpha_x$ = point specific filtration resistance, ft./lb. mass
$\alpha_1$ = value of $\alpha$ when $p < p_1$, ft./lb. mass
$\epsilon$ = porosity
$\epsilon_o$ = constant in Equation (18)
$\epsilon_{o1}$ = value of $\epsilon_o$ for the precoat
$\mu$ = viscosity, lb. mass/(ft.)(sec.)
$\rho$ = liquid density, lb. mass/cu.ft.
$\rho_s$ = true solid density, lb. mass/cu.ft.
$\rho_{s1}$ = true solid density of precoat, lb. mass/cu.ft.
$\rho'$ = constant in Lewis Equation (5)
$\theta$ = time, seconds
$\theta_m$ = time, minutes
$\theta_1$ = time required for pressure drop across cake to reach $p_1$, sec.

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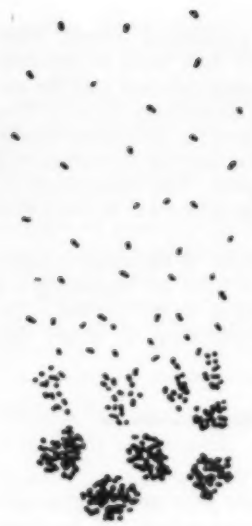
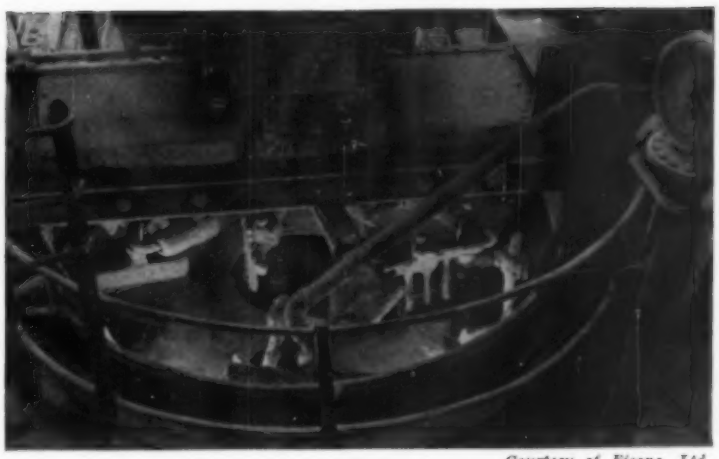
*Presented at Springfield, Mass., meeting.*





Courtesy of Fisons, Ltd.

Fig. 3. Pan-type mixer.

# agglomeration—
## A CHEMICAL ENGINEERING TOOL FOR
# granulating mixed fertilizers

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Agglomeration is receiving much attention as a chemical engineering unit operation for controlling the size, shape, and density of solids systems. In the United States and Europe, improvement in fertilizer product characteristics by agglomeration is being widely adopted (*3, 4, 6, 8, 11, 17*). At present about 80 of the 1,235 fertilizer-mixing plants in the United States are producing granulated fertilizer mixtures, using agglomeration techniques to minimize caking, segregation, dustiness, and poor drillability in the product.

The manufacture of agglomerated fertilizer mixtures poses numerous problems of process design, operation, and control. Some of the chemical engineering aspects of these problems are considered here.

#### Types of Granulation Processes

Two principal types of granulation processes for mixed fertilizers are the slurry and nonslurry methods. In the slurry process an aqueous slurry is formed with one or more of the ingredients of the mixture and then dispersed into agglomerates by the addition of solids during appropriate agitation (*14*). In the nonslurry process the mixture of relatively dry solids is brought into the agglomerate state by the addition of liquid during suitable agitation (*4*).

In one modification of the slurry process used in this country (*12*), the mixture of solids is treated with ammoniating solution and sufficient water to form a hot, thin slurry. This is thickened and congealed by the addition of recycled solid material, and the semiplastic mass is broken up and formed into separate agglomerates by suitable agitation. Subsequent to the agglomeration step the slurry process follows the same general procedure as that employed in the nonslurry process.

As compared with nonslurry, the slurry process in which all of the solid ingredients are initially formed into a slurry requires the presence of more water per unit weight of initial solids in the mixture, and, consequently, more water must be removed in drying the product to the same moisture content. Other than for this difference in the initial stages of the two procedures, the data given here seem equally applicable to both slurry and nonslurry processes, although they were obtained in connection with the nonslurry method.

#### Factors in Agglomeration

Factors influencing the agglomeration of moistened particles to form stable granules include particle-size distribution (*9*), plasticity, solubility, chemical activity, and other physical and chemical properties of the initial material, as well as the cementing action of moisture and salt solutions, deposition of salts from solution, compaction of the agglomerates by physical agitation, and the processing temperature. There is considerable physical and chemical information from past research and plant operation (*6, 17*) that can be used to advantage in the practical application of these factors to agglomeration.

In the agglomeration of mixed fertilizers, small moistened particles are assembled into larger compacted granules in which some of the ingredients retain their original identity and some are transformed into other chemical compounds. The over-all process is commonly referred to as granulation. The principal steps are mixing, ammoniation, agglomeration, drying if necessary, and cooling. The final product consists principally of material in the particle-size range 6 to 20 mesh ($\frac{1}{8}$ to $\frac{1}{32}$ in.). The agglomeration of mixed fertilizers is influenced by several interdependent variables including formulation, level of ammoniation, temperature, liquid-phase volume, and solubility. Thus, the formulation determines the desirable or economic level of ammoniation and, consequently, the thermal effects that will be encountered. The volume of the liquid phase is a function of formulation in relation to the moisture content of the mixture, solubility of the ingredients, and the temperature.

For a specific formulation, moisture content is the most readily controlled variable affecting the tendency of the

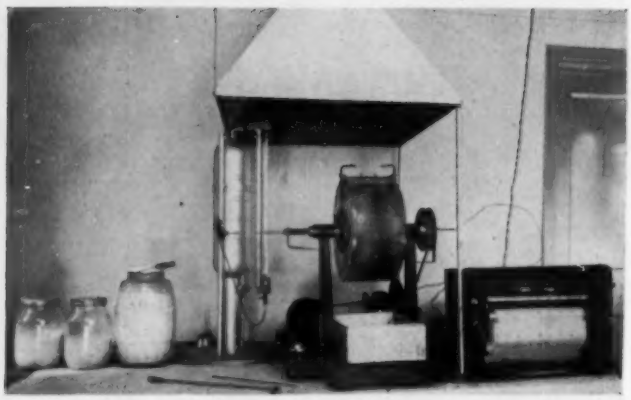


Fig. 1. Small-scale rotary ammoniator and granulator.

mixture to agglomerate. Within limits, the liquid-phase volume and the tendency of the mixture to agglomerate are dependent on temperature as well as moisture content. In consequence, agglomeration to the point at which a maximum proportion of the material is obtained in the desired particle-size range, under otherwise fixed operational conditions, is related to the imposed moisture and temperature relationships, therefore, agglomeration will now be referred to as "optimum agglomeration."

### Formulation

Considering that 1,439 grades of mixed fertilizer, each capable of being formulated in a number of ways, were marketed in the United States and territories in 1952–53 (*16*), it is to be expected that in practice the conditions for agglomeration will vary greatly. Although only 177 grades accounted for 97.5% of the total tonnage, the number of possible formulations of these grades that may require different conditions for their agglomeration is still very large.

Table 1 gives the formulas for two 10-10-10 mixtures that differ considerably in the kind and proportion of their ingredients and in the conditions required for their agglomeration. The principal differences in formulation relate to the respective proportions of the several nitrogen carriers and to the inclusion of sulfuric acid in Mixture 2. A plant designed with sufficient flexibility to granulate satisfactorily these two mixtures should be suitable for granulating a wide variety of other mixtures formulated with the same kinds of ingredients.

It is customary to overformulate mixed fertilizers to the extent of 0.1 to 0.5 unit * of each plant nutrient in order to compensate for possible losses during and subsequent to their manufacture. This practice was followed in formulating the mixtures described in Table 1. Mixture 1 contains an amount of ammoniating solution comparable to that used in many currently manufactured mixtures. Thus, 5.68 units of nitrogen are supplied by the solution and 4.46 units by ammonium sulfate. Mixture 2 contains 8.56 units of nitrogen from ammoniating solution and the remainder from ammonium nitrate. The sulfuric acid used is stoichiometrically equivalent to the increase in neutralizing ammonia supplied. The ammonium nitrate content of Mixture 2 is twice that of Mixture 1.

These examples of formulation serve as a convenient basis for examining the general processing conditions that influence the agglomeration of mixed fertilizers.

* In fertilizer parlance a unit is 20 lb.

### General Processing Conditions

#### AMMONIATION

The treatment with neutralizing ammonia of superphosphate and mixtures containing superphosphate is an established practice in the fertilizer industry. It utilizes anhydrous ammonia and ammoniating solutions—the least expensive sources of fertilizer nitrogen. The solution mentioned in Table 1 is a typical commercial product. The ammonium nitrate in the solution not only is a nitrogen carrier but also reduces the vapor pressure of the solution and thus facilitates its handling in the fertilizer plant. Under favorable conditions in commercial ammoniation of mixed fertilizers, ordinary superphosphate will readily absorb and retain as much as 6 lb. neutralizing ammonia per unit of $P_2O_5$, as compared with 4 lb. per unit for triple superphosphate (*7*). The lower absorption rate for triple superphosphate is due to its limited content of calcium sulfate. Ordinary superphosphate contains considerably more calcium sulfate than is necessary for the ammoniation reactions; hence, its predominance in Mixture 1 ensures the absorption of ammonia on the same basis as in Mixture 2 where it is the sole source of $P_2O_5$. Consequently, both

**Table 1.—Formulas of 10-10-10 Grades of Mixed Fertilizer**

| Material | | Mixture 1 | | | | Mixture 2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Units | | | | Units | | |
| Kind | Analysis, % | Weight, lb./ton | N | $P_2O_5$ | $K_2O$ | Weight, lb./ton | N | $P_2O_5$ | $K_2O$ |
| Ordinary superphosphate | 20.0 $P_2O_5$ | 866 | .... | 8.66 | .... | 1,034 | .... | 10.34 | .... |
| Triple superphosphate | 48.0 $P_2O_5$ | 77 | .... | 1.85 | .... | ... | .... | .... | .... |
| Ammoniating solution * | 40.6 N | 280 | 5.68 | .... | .... | 422 | 8.56 | .... | .... |
| Ammonium nitrate | 33.5 N | ... | .... | .... | .... | 96 | 1.61 | .... | .... |
| Ammonium sulfate | 20.5 N | 435 | 4.46 | .... | .... | ... | .... | .... | .... |
| Sulfuric acid | 85 $H_2SO_4$ | ... | .... | .... | .... | 106 | .... | .... | .... |
| Potassium chloride | | 2,000 | 10.14 | 10.51 | 10.26 | 2,000 | 10.17 | 10.34 | 10.26 |
| Total | 60.0 $K_2O$ | 342 | .... | .... | 10.26 | 342 | .... | .... | 10.26 |

* The ammoniating solution contains 21.7% neutralizing ammonia, 65% ammonium nitrate, and 13.3% water. The amounts of solution in Mixtures 1 and 2, respectively supply 61 and 92 lb. ammonia, 182 and 274 lb. ammonium nitrate, and 37 and 56 lb. water.

mixtures are formulated so that 5 lb. neutralizing ammonia reacts with 1 unit of $P_2O_5$.

The primary products of the reaction between ammonia and the superphosphates in both mixtures (Table 1) are dicalcium phosphate and monoammonium phosphate (*2, 18*). When the absorption of ammonia by the superphosphates in these mixtures exceeds 2.4 lb. per unit of $P_2O_5$, the primary products and the additional ammonia react with calcium sulfate to form more basic phosphates (*7, 10*) and ammonium sulfate, according to the equations:

$$NH_4H_2PO_4 + CaSO_4 + NH_3 \rightarrow CaHPO_4 + (NH_4)_2SO_4 \quad (1)$$

$$2CaHPO_4 + CaSO_4 + 2NH_3 \rightarrow Ca_3(PO_4)_2 + (NH_4)_2SO_4 \quad (2)$$

Within limits, the efficiency of ammonia absorption is enhanced by increasing the moisture content of the mixture. Ammoniation, therefore, is particularly well adapted to the agglomeration procedure because the amount of moisture required for agglomeration usually is higher than that normally present during the processing of nongranular mixtures. On the other hand, the efficiency of absorption decreases with increase in particle size of the superphosphate, and consequently it is essential that ammoniation precede agglomeration. In order to obtain high efficiency of ammonia absorption and also uniform distribution of plant nutrients among different-sized fractions of the product, the initial solid materials usually are ground to pass a 10-mesh, or finer, sieve.

#### EFFECTS OF HEAT DEVELOPED BY REACTION

The heat developed when superphosphates are treated with 6 lb. anhydrous liquid ammonia per 20-lb. unit of $P_2O_5$ has been found to be equivalent to 1,426 Btu./lb. ammonia absorbed for ordinary superphosphate and 1,589 Btu. for triple superphosphate (*2*).

The resultant increase in temperature is an advantage in the agglomeration procedure because it increases the volume of the liquid phase in respect to the moisture content. The high temperature keeps the salt in solution during agglomeration, provides a maximum volume of liquid phase for agglomeration at low moisture content, and aids in subsequent drying of the granular product. Incorporation of sulfuric acid, as in Mixture 2, permits the use of more neutralizing ammonia and the development of still higher temperature.

The increase in temperature, $\Delta T$, may be readily estimated from the known specific heats of the fertilizer salts (*2, 13*) and ammoniated superphosphates (*2*) with the use of the formula,

$$\Delta T = H/MC,$$

where $H$ is the heat developed by chemical reaction, $M$ the mass of the ammoniated mixture, and $C$ the heat capacity of the product.

Satisfactory physical condition in the product is favored by reducing the moisture content of the granulated mixture to 2.5% or less. This usually is less moisture than the nongranular mixture contains because of the relatively high moisture contents of its ingredients. Consequently, the final analysis of the granulated mixture with respect to N, $P_2O_5$, and $K_2O$ frequently is higher than the analysis indicated by the formula. Accurate knowledge of the moisture contents of initial ingredients thus enables the manufacturer to formulate on the basis of the moisture content of the final product.

**Table 2.—Sources and Quantities of Water for Agglomeration of 10-10-10 Mixed Fertilizers**

| Water in: | Pounds per Formula Ton | |
|---|---|---|
| | Mixture 1 | Mixture 2 |
| Solids | 40 | 54 |
| Ammoniating solution | 37 | 56 |
| 85% $H_2SO_4$ | None | 16 |
| Subtotal | 77 | 126 |
| Water added to agglomerate | 166 | None |
| Total water at agglomeration | 243 | 126 |
| Total weight of mixture at agglomeration | 2,166 | 2,000 |

#### MOISTURE CONTENT AND LIQUID PHASE

The volume of the liquid phase is dependent on the solubilities and amounts of soluble salts present in the mixture, as well as on the moisture content and temperature (*3, 5, 6*). Although this volume is not readily determined, as indicated by the work of Rader (*15*), its influence on agglomeration is generally recognized, since moisture requirements for agglomeration usually can be correlated with highly soluble salt content and temperature of the mixture. Of the fertilizer salts commonly used in mixed fertilizers, urea and ammonium nitrate are by far the most soluble and also exhibit the greatest increases in solubility with increases in temperature. By virtue of these properties they tend to increase the volume of the liquid phase to a much greater extent than do any of the other common fertilizer salts.

Accurate moisture analysis of materials entering the process is important to the control of agglomeration. Frequently the moisture content of the initial mixture exceeds the critical value for agglomeration. An excess of as little as 1% moisture may produce a large proportion of oversize nodules, and a somewhat greater excess may produce a slurry which requires thickening in order to yield agglomerates. Recirculation of dry fines from a sizing step in the latter stages of the process may be used to control agglomeration.

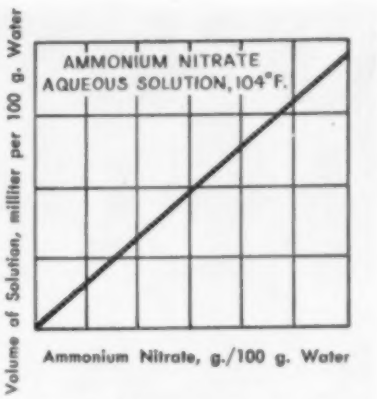



Fig. 2. Effect of concentration on volume of ammonium nitrate solution.

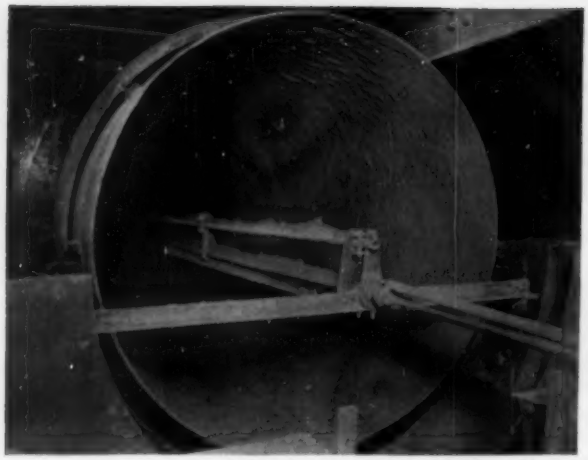
## agglomeration

#### Agglomeration of 10-10-10 Mixtures

Useful data on the moisture requirement for agglomeration may be obtained with the aid of the apparatus shown in Figure 1, whereby increasing increments of water are added, with ammoniation, to successive batches of mixed fertilizer in a 3-gal. rotary drum until optimum agglomeration is obtained. Under these conditions optimum agglomeration usually corresponds to a yield of 65 to 80% of granules in the particle-size range of 6 to 20 mesh. The test is usually conducted at 190 to 200° F. by supplementing the heat derived from ammoniation with that from a gas flame applied to the outer surface of the drum. This is necessary to compensate for heat losses which are extensive in small-scale tests.

#### MOISTURE BALANCE AND THE LIQUID PHASE

Data derived from small-scale tests on the 10-10-10 mixtures described in Table 1 are given in Table 2. The source and quantity of water for agglomeration are shown for each mixture. The data are derived from the known moisture contents of initial materials and the moisture analyses of the freshly agglomerated mixtures obtained in tests



Courtesy of Sturtevant Engineering Co., Ltd., London.

Fig. 4. Rotary cylinder.

conducted at a temperature of 194° F. Mixture 1 required 166 lb. water, in addition to that supplied by the ingredients of the mixture, to give optimum agglomeration. Thus the total moisture content at the agglomeration point was 243 lb./2,166 lb. material, or 11.2%. Mixture 2 required no additional moisture to give optimum agglomeration, and the total moisture content at the agglomeration point was only 126 lb./2,000 lb. material, or 6.3%. In both cases the water present was more than sufficient to dissolve all of the ammonium nitrate present. The concentrations of the ammonium nitrate solutions in the two cases correspond to 75 and 290 g. $NH_4NO_3$/100 g. water for Mixtures 1 and 2 respectively.

Presumably the volumes of liquid phase per unit of effective surface area in the two mixtures were substantially equivalent in order to produce agglomeration. Evidence of this is obtained from Figure 2 which shows the volume of solution obtained with increasing amounts of amonium nitrate dissolved in 100 g. water. In accordance with this figure the solution volumes corresponding to the ammonium nitrate contents of Mixtures 1 and 2 are 148 and 287 ml. respectively, per 100 g. water. Thus, neglecting the effect of the presence of other soluble salts, the volume of liquid phase attributable to the ammonium nitrate in Mixture 1 is $2.43 \times 148$, or 360 ml./g. formula weight, and in Mixture 2, $1.26 \times 287$, or 362 ml. The close agreement between these values indicates that the lower water requirement for agglomeration of Mixture 2 resulted primarily from the higher ammonium nitrate content.

#### TEMPERATURE–MOISTURE RELATIONSHIPS

From values cited earlier for heat developed during ammoniation, and neglecting the difference between the state of ammonia in anhydrous liquid form and in ammoniating solutions, it is estimated that the heat developed per pound of ammonia reacting in Mixture 1 is 1,439 Btu., and in Mixture 2, 1,426 Btu. The total heat liberated in Mixture 1 with 61 lb. of ammonia is about 87,800 Btu. In Mixture 2 the amount of ammoniating solution used contains 92 lb. neutralizing ammonia, of which 61 lb. is assumed to react with superphosphate and 31 lb. with 90 lb. sulfuric acid. The heat liberated by the superphosphate-ammonia reaction is about 87,000 Btu., and that calculated from the heats of formation (*1*) of the sulfuric acid, ammonia, and ammonium sulfate is approximately 75,200 Btu. Thus the total heat developed in Mixture 2 is estimated to be 162,200 Btu., as compared with 87,800 Btu. developed in Mixture 1.

The calculated heat capacities of Mixtures 1 and 2 are 0.354 and 0.317 respectively. With the use of these values and with the assumption of an ambient temperature of 77° F., the heat developed in Mixture 1 is sufficient to raise the temperature to 192° F., while in Mixture 2 it is sufficient to raise the temperature to 212° F. and to vaporize 79 lb. water.

The effect of processing conditions on moisture removal and nutrient levels in each of the two mixtures is shown in Table 3. To reduce the moisture content of Mixture 1 to 2.5% requires sufficient additional heat to remove 194 lb. water, but no additional heat is required for Mixture 2. Owing to the low moisture contents of the respective products, the total weights of major plant nutrients (N, $P_2O_5$, and $K_2O$) are 9 and 24 lb. more than required. Thus, close control of moisture during processing to the levels shown in Table 3 would allow formulation of Mixture 2 on the basis of 9.77-9.93-9.85 to give a product analyzing 10.17-10.34-10.26, corresponding to the analysis of the original formula shown in Table 1.

The foregoing data indicate types of information that seem essential as a basis for designing new processes or for evaluating the adequacy of existing processes for granulating mixed fertilizers. Such information should take into account (1) the types of formulas to be processed, (2) the physical and chemical properties of the initial materials, (3) the heat development and temperature rise owing to ammoniation, (4) the water requirement for optimum agglomeration, and (5) methods and equipment for measuring and controlling the moisture–temperature relationships during processing. This approach to process design should be useful in solving many of the problems in process operation and control.

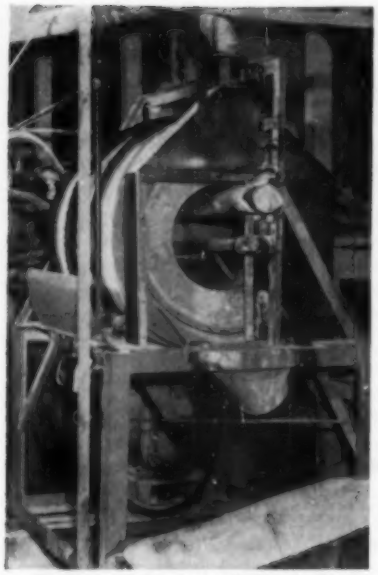
### Types of Equipment

#### THE PAN-TYPE MIXER

**The pan-type mixer (Figure 3) is used for batch agglomeration of mixed fertilizer. A typical pan is 7.5 ft. in diam. and 18 in. deep. Rotation of the pan and mixing blades (which**

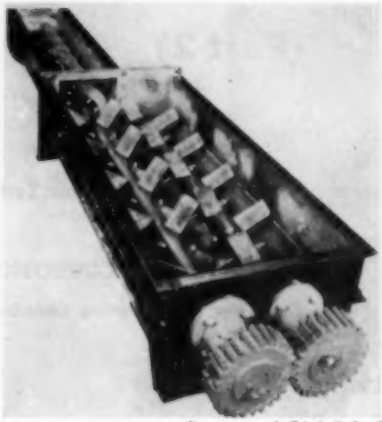
**Table 3.—Effect of Processing Conditions on Moisture Removal and Nutrient Levels of 10-10-10 Mixed Fertilizers**

| | Mixture 1 | Mixture 2 |
|---|---|---|
| | Pounds per Formula Ton | |
| Total weight of mixture at agglomeration | 2,166 | 2,000 |
| Water removed during processing | 194 | 79 |
| By heat of ammoniation reactions | None | 79 |
| By drying to 2.5% moisture | 194 | None |
| Total weight of final product | 1,972 | 1,921 |
| Total N, $P_2O_5$, and $K_2O$ | | |
| In final product | 618 | 615 |
| Required in final product | 609 | 591 |
| Excess, or overformulation | 9 | 24 |
| Grade of final product | 10.28–10.66–10.41 | 10.59–10.76–10.68 |



Courtesy of Tennessee Valley Authority

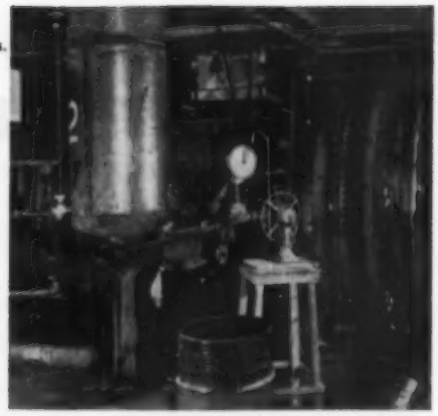
Fig. 5. TVA continuous ammoniator.



Courtesy of Link-Belt Co.

Fig. 6. Twin-shaft pugmill.

Fig. 7. Twin rotary batch mixers.



Courtesy of Eastern States Farmers' Exchange, Inc.

are eccentric to the pan) in opposite directions maintains the charge in a constant state of agitation. Under these conditions, sufficient water is added to produce the degree of plasticity required for the formation of agglomerates. Agitation is continued for 2 to 3 min. to complete agglomeration and compact the agglomerates. The granules are discharged through a floor valve to a smoothing hopper and fed at a controlled rate to a drier.

## ROTARY CYLINDER

A slightly inclined rotating cylinder (Figure 4) is frequently used for continuous agglomeration of mixtures. Such agglomerators vary in size, but a typical one, inclined at 2° from the horizontal and rotating at 8 rev./min., is 6.5 ft. in diam. and 18 ft. long. The operator, stationed at the discharge end, controls the continuous addition of water to the material on the basis of the appearance of the moist agglomerates as they approach the outlet end of the cylinder. A buildup of "skin" or mud is maintained on the smooth wall of the cylinder to reduce slippage of the material and promote the rolling and tumbling action necessary for the formation of agglomerates. In another procedure the rotary cylinder is used merely to compact agglomerates which are formed in a previous step of the process.

The TVA continuous ammoniator (Figure 5) (19) may also function as a granulator. It consists of a rotating cylinder of approximately equal diameter and length, with retaining rings at each end. The ammoniating medium is introduced through a multiple-outlet, slit-type distributor beneath the surface of the rolling bed of solids. The mechanical action of this equipment promotes agglomeration under favorable conditions of liquid and solid contents and temperature of the rolling bed of material.

## PUGMILLS

Both single- and twin-shaft pugmills are used for obtaining a thorough mixture of solid and liquid phases at the agglomeration point. The twin-shaft pugmill (Figure 6) is used to mix the slurry as well as to break up the thickened material in the slurry process.

Various types of single-shaft pugmills are used for mixing and ammoniation in both continuous- and batch-processing methods in which the ultimate aim is to obtain a granular product.

## ROTARY BATCH MIXER

The conventional rotary batch mixer, used for many years in mixing and ammoniating nongranular fertilizers, has been employed recently as an agglomerator. However, batch agglomeration does not provide an even flow of material to subsequent stages of the process. Attempts to alleviate this difficulty by the use of retaining hoppers and smoothing devices have not proved entirely satisfactory. In some plants these mixers are used in pairs (Figure 7) in such a way that one discharges while the other is agglomerating another batch. Batch agglomeration is not well adapted to the practice of returning recycle material to the agglomeration step.



**Acknowledgment**

Grateful acknowledgment is made to companies and agencies furnishing photographs of equipment and to Andrew Szabo and Joseph G. Cummings for making the agglomeration tests on the two mixtures discussed.

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*Presented at A.I.Ch.E. Glenwood Springs, Colorado, meeting.*

# NIONEL REFERENCE SHEET

## (Part 2)

*W. Z. Friend*

International Nickel Company, Inc., New York

### LABORATORY CORROSION TESTS DATA

#### Phosphoric Acid

Tests in hot phosphoric acid solutions indicate very useful resistance. The results of laboratory corrosion tests of several alloys in boiling 85% phosphoric acid are shown in the following table. The corrosion rates shown are for three-24-hour test periods:

**Laboratory Corrosion Tests in Boiling 85% Phosphoric Acid**

| | Corrosion Rate, inch per year | | | |
|---|---|---|---|---|
| Material | Period 1 | Period 2 | Period 3 | Ave. |
| Hastelloy B | 0.004 | 0.005 | 0.003 | 0.004 |
| Nionel | 0.036 | 0.035 | 0.034 | 0.035 |
| Hastelloy C | 0.114 | 0.156 | 0.130 | 0.133 |
| Type 316 Stainless | 0.427 | 0.432 | 0.477 | 0.445 |

Nionel should find useful application in such processes as hydrocarbon polymerization using phosphoric acid as catalyst in petroleum and petrochemical plants; also in processes for the application of phosphate coatings to steel. A principal field for which the alloy is suggested is the wet process for production of phosphoric acid by treatment of phosphate rock with sulfuric acid. The hot mixture of phosphoric and sulfuric acids plus certain amounts of fluorides and ferric salts is particularly corrosive and preliminary tests indicate useful resistance for Nionel.

*(Continued next month)*

### PLANT CORROSION TESTS DATA

**Tests Made in Operating Chemical Process Equipment in Plants**

| Corrosive | Duration of test, days | Temp., °F | Corrosion Rate, in./yr. |
|---|---|---|---|
| Aluminum chloride plus water-variable concentrations. Immersed in tank. Strong agitation. | 30 | 120–195 | 0.004 |
| Wash water used to scrub gases containing 0.25% ammonium chloride and 0.20 to 0.44% sulfuric acid. pH 1.6 to 10, depending upon ammonia carry-over. Aerated and agitated. | | | |
| a. Immersed in sump. | 11 | 50–150 | 0.0001 |
| b. In pipe line. | 8 | 50–150 | 0.0002 |
| 15% ammonium fluoride solution with excess ammonia. pH moderately basic. Immersed in closed reaction vessel. Strong agitation. | 94 | 60–200 | ∠0.0001 |
| 50% to 100% ammonium bifluoride in ore treatment. Alternately evaporated to dryness and diluted. | 10 | 80–390 | 0.007 |
| Carbon black slurry in water. Immersed in slurry tank. Mild agitation. | 21 | 160–180 | ∠0.0001 |
| Carbon black slurry containing 7% carbon black, 0.45 gm/gal. chlorides, 6.6 gm/gal. sulfates, pH 6.5-6.8. Immersed in rundown tank. Agitated. | 30 | 160–180 | 0.0005 |
| Mixture of organo-chlorosilanes, hydrogen chloride and amines. In reaction vessel. Agitation. | | | |
| a. Immersed in liquid. | 3 | 260–285 | 0.011 |
| b. In vapor. | 3 | 260–285 | 0.007 |
| Chlorine dioxide-water solution containing 4-5 gpl. $ClO_2$. pH 2-3.5. Immersed in receiving tank | 15 | 36 | 0.0010 |
| 32% sodium perchlorate plus 66° Bé sulfuric acid in generation of chlorine dioxide gas for pulp bleaching. | 15 | 135 | 0.042 (Severely pitted) |
| Ethylene dichloride, steam and oil in treating tower. | 18 | 210–240 | 0.002 |
| Fatty acids, nitriles, ammonia and steam. Immersed in hot vapor stream in reactor. | 88 | 590 | 0.006 |
| Fatty acids ($C_{12}$ to $C_{18}$) and primary alcohols plus 0.1 to 0.25% sulfuric acid in esterification still. | 100 | 200–265 | 0.003 |
| Molten fluorides in aluminum brazing flux. | 32 | 1100 | 0.013 |
| Flue gas containing $SO_2$, $SO_3$, $H_2O$ and air. In cold end of air heater. | 158 | 350 | 0.004 |
| Hydrochloric acid—triethanolamine slurry in mixing vessel. | 15 | 90–220 | 0.0002 |
| Crude nitric acid mixture containing 3N free nitric acid; 2.7N combined nitrates of Fe, Cu, Co and Ca; 20 gpl. calcium sulfate; 50 ppm chlorides. Immersed in reflux flask. | 10 | 195 | 0.0004 |
| Crude nitric acid mixture containing 5.5N free nitric acid; 2.5N sulfates of Fe, Cu, Co and Ca; 50 ppm chlorides. Immersed in reflux flask. | 10 | 195 | 0.013 |

*(Continued next month)*

**No. 46**

Plate assembly about to enter vacuum brazing furnace at C.B. & I.'s Birmingham plant.

# VACUUM BRAZED CLAD METAL NOW COMMERCIAL REALITY

***Ingeniously simple method for cladding steel produces stock meeting code requirements—Unusual dimensional and surface finish stability among advantages. . . . Major fabricator of process vessels to be producer. . . . Volume estimated to increase total U. S. tonnage by 20%. . . . Firm's management employs well-known consultant group to plot market—predict course. . . .***

The chances are you may have heard of Hortonclad*—the clad metal produced by an almost revolutionary vacuum brazing process outstanding for its simplicity and close tolerance over dimensions. The chances are equally good however, that you haven't as yet had any vessels fabricated of it. Until a few weeks ago, this promising process was still "under wraps"—or, more specifically, under development. Now, the wraps are not only off, but the product is available in considerable tonnages.

First announced in 1952, it was discussed but not promoted by Chicago Bridge & Iron Co. at the 1953 Philadelphia Chemical Show. The interesting new clad metal then soon disappeared from the commercial scene. Reason: Need for further development, larger production facilities. Time has permitted broadening range of metals which can be bonded commercially. New plant recently completed at Birmingham, Alabama is already capable of producing only what C.B.&I.* estimates as their own needs. All of which means that for the time being, you may be able to get what you want, but it will have to be fabricated to your design by C.B.&I.

**What It Is**

Hortonclad for all practical purposes is termed equivalent mechanically to conventional hot rolled clad metal or alloy. It meets all requirements of the ASME Boiler Code and the API-ASME Code for Unfired Pressure Vessels. Its bond between layers is good enough to attain well beyond the required minimums of tensile strength and pass the 180° bend and other tests to meet ASTM standards for integrally and continuously clad plate. Such vacuum-brazed claddings consist of the conventional outer layer bonded to the backing or base plate by a brazing metal or alloy. The latter is usually copper or a copper alloy.

**How It's Made**

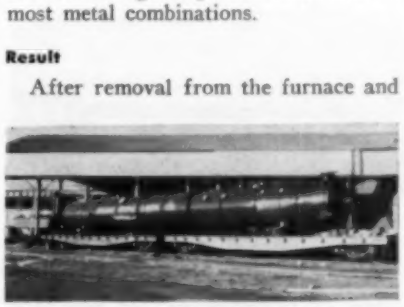
In assemblying the "package" for brazing, both face sheet and base plate are descaled according to conventional shop operations. Somewhere in the procedure a hole is drilled and tapped through the center of the base plate. Over this plate is laid a sheet of very thin copper or copper alloy foil—the brazing material. On top of this is laid the face sheet.

The edge of this package assembly is brazed all the way around, to make the inside air-tight. A vacuum line is connected to the hole in the base plate, and the assembly is pushed into a brazing furnace. A vacuum of 29-30 in. Hg. is drawn on the inside of the package, and the temperature of the furnace is raised to something just above the melting point of the brazing metal.

While the brazing metal is molten, the evacuation of the inside of the package results in atmospheric pressure being applied uniformly over the surfaces of the package—pressing the layers together firmly. At the same time, the vacuum removes any gases that may be formed, and drains off any excess molten brazing metal. Ordinary air is allowed as the "atmosphere" in the furnace—the temperatures reached are low enough to prevent oxidation of most metal combinations.

**Result**

After removal from the furnace and cooled, the composite plate's edges are trimmed. The assembly now securely and uniformly clad—has the same surface conditions as when it entered. The thickness of the clad plate is extremely uniform—variations are so minor as to not be of importance for ordinary process vessel design.



Monel and stainless Hortonclads used for this 7½-ft. by 81-ft. tower.

**Fabrication**

Ordinary fabricating techniques, such as rolling, bending, flanging and dishing can be carried out as for conventional hot-rolled clad metal. It is understood that pressing of heads is preferable to spinning.

Welding of vacuum brazed composite metal offers no problems provided that recognition is given the presence of the layer of copper present in the bond interface. Care should be taken to use electrodes or rods of material in which copper is highly soluble (such as nickel, Inconel, Monel or Hastelloy F or B).

**Corrosion Resistance**

The effect of traces of copper in the weldment on corrosion resistance should be reckoned with if vacuum brazed clad metal is to be considered for contact with solutions which might be copper-sensitive.

*(Continued on page 36)*

* Hortonclad is a trade name referring both to product and process by which it is produced, and is owned by *Chicago Bridge & Iron Co.

(*Continued on page 35*)

According to C.B.&I., their development efforts succeeded in devising brazing conditions which limit the diffusion of copper from the brazing interface, into either base or face layers. To quote their statement directly (1), "It has been determined that through strict control of heating, holding and cooling cycles, also subsequent heat treatments, if used, the proper amount of alloying can be obtained at the brazing interface to attain exceptionally high bond strengths with appreciable loss of ductility."

#### What Can Be Clad?

The following are commercially available, as bonded to carbon steel: Chromium, chromium-nickel, Monel, Inconel, nickel, and nickel alloys that will meet ASTM specifications A-263, A-264, and A-265. These include stainless steel types 304, 316, 316 ELC, 347, 405 and 410. Hastelloys B, C, and F are likewise available.

Under development study are molybdenum, copper, Multimet and Haynes Hi-Cobalt (alloy No. 25) on carbon steel, plus copper on stainless. Commercially possible but so far unattractive because of difficulties in welding both face and backing plates, is tantalum on carbon steel.

#### Size Limits

Vacuum brazed clad plates are produced by C.B. & I. in dimensions up to 10 by 38 ft. Thicknesses vary according to materials used; however a general range for base plates is ¼ to 1¼ in., plus 1/16 to ½ in. for alloy layer. Base plates up to and including 4 inches thick have been commercially cladded.

#### Market Situation—for present

For the presnt, C.B. & I. states they will both supply Hortonclad directly to those specifying it, or will propose Hortonclad on vessel construction which carries the customary specification for hot-rolled clad metal.

All Hortonclad is to be produced (for the time being) at Birmingham, Alabam, feeding the firm's fabrication shops at Birmingham, Chicago, Ill.; Greenville, Pa., and Salt Lake City, Utah.

#### Market Situation—as per survey study

To fathom where its entry into the clad metals production business might take the firm, C.B. & I. employed Arthur D. Little, Inc. (consultants, of Cambridge, Mass.) to make an extensive survey with managerial recommendations. Techniques employed by A.D.L. included a field interview survey of customers and competitors.

**One of the outstanding facts to come out of this study is that an equipment fabricator—C.B. & I.—who normally consumes 1/5 of the total clad metal produced in the U. S. to supply its customers of fabricated vessels, will henceforth be dropping out of the picture as a clad metal buyer, and will be adding considerably to the national production. A total of nine major process equipment fabricators has been shown to consume 80% of the total annual tonnage of clad steels produced in this country.**

**Further shown are that: 70-75% of clad steels produced are stainless steel backed with low carbon steel.**

**—90% (on a tonnage basis) of stainless facings employed are types 304, 316, 405, and 410. Of these, types 304 and 316 account for 70% of the 90%.**

**—The process industries, through movement towards higher pressures and temperatures and greater complexities of corrosives, are spurring accelerated research and development activities for new and superior metals. The report goes on to state, "Alloy steels, in one form or another, dominate the market."**

**—Since 1939 there has been an increase of approximately 2000% in consumption of clad steel with the major increase since 1949. This compares with an increase of approximately 1000% in the consumption of solid stainless.**

**—The greatest volume concentration of stainless clad is in the ranges of ¼ to ½ in. overall thickness of composite plate. This compares with a range of the same sizes for solid stainless.**

**—In 1954, the chemical, petroleum refining, and atomic energy industries consumed ¾ of the total tonnage of clad steels produced. The breakdown of this is (for 1954): Chemicals 27%, atomic energy 21%.**

The survey report recommends to the C.B. & I. management, the specific market directions to be followed, a timetable for accomplishment, with particular emphasis on the potential market for specialty clad metals (combinations not available as yet through hot rolling).

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**New C.B. & I. vacuum brazing plant at Birmingham, Ala.**

**Further information may be had by encircling number 100 on Data Service Card, page 54 of this issue.**

**Late news of —**

## Kanigen* Alcoplate**

In an earlier issue (*C.E.P.* January '55, p. 60), the Kanigen and Alcoplate processes for the "electro-less" deposition of nickel were described.

Electroless nickel coatings deposit an alloy containing approximately 92.5% Ni, 7% P, and the balance of Co, O, and Ca. The film deposits evenly and without porosity, producing a surface microscopically identical to that underneath . . . over a highly polished surface the nickel goes on "bright," over a rough surface, "rough." Films are deposited commercially in thicknesses from 0.2 to 20 mils, although the usual practical economic maximum is 5 mils.

Kanigen is described by GATX as being successfully applied to wrought iron, cast iron (machined surfaces coat excellently; coating as-cast surfaces may produce porous result depending on the quality of the casting), steel (including stainless), copper, brass, bronze, and aluminum. Most alloys of iron, copper and aluminum tested have been coated satisfactorily. On some of the special alloys, however, special pretreatment techniques are required.

In general any part or vessel can be Kanigen (or for that matter, Alcoplate) coated that can be immersed in a tank or through which solutions can be pumped. This is subject to the restriction brought about by evolution of gas from the plating solution while the deposition is taking place. Care must therefore be taken to prevent its entrapment, which would isolate part of the surface from contact with the plating solution. American Locomotive reports coating vessels up to 5-ft. diam. by 45-ft. long.

Extremely large vessels such as storage tanks can be electroless nickel plated but normally this would not be feasible because of the large volume of cleaning and coating solutions required. GATX's E. Chicago plant can handle tanks up to approximately 3,000 gallons capacity.

Cleaning of surfaces prior to electroless plating is of utmost importance, ranking with gas removal during plating and accurate control of plating solution (around 212° F.) as a major controlling factor as to size and complexity of items which can be plated. While cleaning methods conventional to electroplating are used, meticulous care must be taken in thoroughness, and removal of oil and dirt from cleaning solutions to produce uncontaminated surfaces.

An advantage of electroless plating is that vessel is plated after fabrication.

* T.M. of General American Transportation Co.
** T.M. of American Locomotive Co.

(*Continued on page 66*)

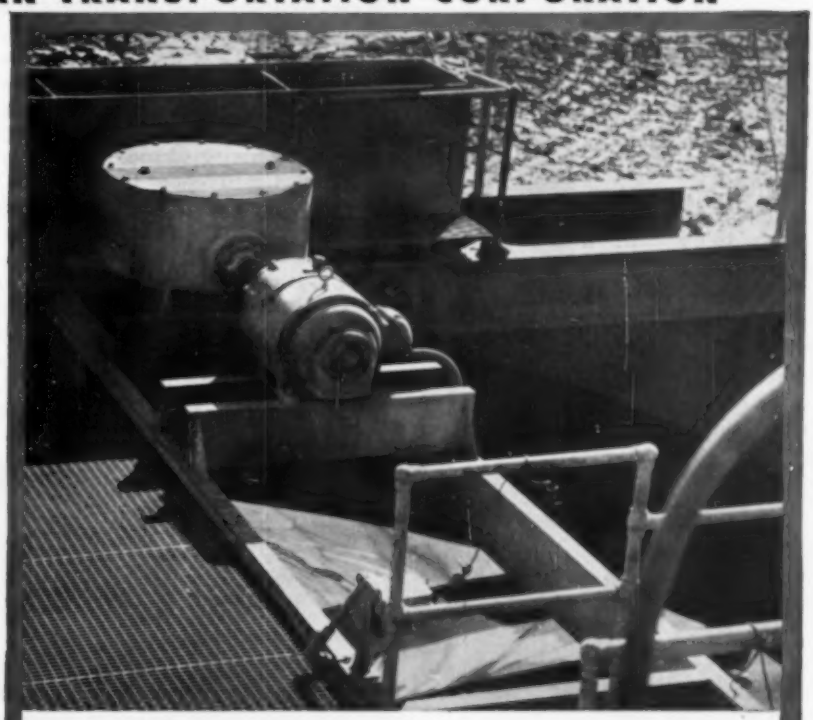
# Turbo-Topics

TURBO-MIXER GENERAL AMERICAN TRADE MARK

**TURBO-MIXER,** a division of

**GENERAL AMERICAN TRANSPORTATION CORPORATION**

## 100,000 hours of round-the-clock service with TURBO on the job



*One of the two Turbo-Mixers installed in 1941 at Universal Atlas Cement Company at Northampton, Pennsylvania, in cement slurry suspension.*

Today, after *100,000 hours* of heavy-duty, *24-hour service*, these Turbos continue to operate with no more than normal plant maintenance. They are typical of the thousands of Turbos operating in continuous-flow processes where "down-time" is critical—where low maintenance is essential.

Turbos can help solve your agitation problems, whether your business is petroleum processing, chemicals, pharmaceuticals or minerals beneficiation. Turbo's built-in ruggedness that permits continuous 24-hour heavy-duty service assures you of "headache-free" production and lower costs in the long run.

**SALES OFFICE: 380 MADISON AVENUE, NEW YORK 17, NEW YORK**

*General Offices:* 135 S. La Salle St., Chicago 90, Illinois • Offices in all principal cities

**OTHER GENERAL AMERICAN EQUIPMENT:—DRYERS • DEWATERERS TOWERS • TANKS • PRESSURE VESSELS**

# HOUSTON

## Some Ways the C. P. I's. will benefit . . .

**In brief:** Cloud seeding no longer *just* for meteorologists! Chemical engineers now applying similar techniques creating showers of carbon black (Sweitzer & Heller, Columbian Carbon), & shale oil (Putman, Bureau of Mines), from gas and vapor "clouds" . . . Same technique applied to seeding of *liquids* producing more desirably-sized pigments (O'Shaughnessy & Varnum, National Lead) . . . Most surprising application of nucleation concept was use as tool which may ultimately supply answer to question: "what will we have to do to prepare solids so we can grind them more efficiently?"—(Simmonds, Dominion Tar & Chemical) . . .

**Large volumes of pure water**—important for nuclear reactors and many other of today's applications . . . Formerly obtained by laborous and expensive distillation . . Development of a large deionizer which does jobs simply, revealed (Monet, Du Pont) . . .

**Wear resistant** materials important to chemical processors described (Lutes & Reid, McKay Co.) . . . Glycol solutions keep gas pipelines from freezing-up with hydrates (Scauzillo, Magnolia) . . . How to design your high temperature reforming furnace (McCarthy, Chemical Construction Corp.) . . . New economic process removes juice from sugar beets by literally "shooting" beets against a baffle (Brownell, Zieminski & Lee, U. Michigan) . . . Corn gluten—literally a mess when it comes to filtration—now successfully handled on a rotary filter! Can you apply same techniques to similarly difficult materials? (Martin, Shepman & Dahlstrom, Eimco) . . .

**Seems that chemical engineers** are getting into the "drilling" for oil—if one reads between the lines of the several papers correlating the theoretical knowledge of fluid flow in porous media with what happens in a petroleum reservoir . . . (by Atlantic, Stanolind, Union, Magnolia, Humble & U. Texas authors) . . .

**Centrifugal extractor** reported on again (Jacobsen & Beyer, Iowa State) . . . Pulsed columns of radioisotope fame in another non-atomic application (Li & Newton, Georgia Tech) . . . Chemical reactions in turbulent flow had their temperatures taken (Corcoran & Sage, Cal Tech) . . . Sieve plate efficiency again reported (Rush & Stirba, DuPont) . . .

**Infrared Analyzers** control a large butenes-2 separation column at Borger, Texas (Campbell, Phillips Chemical, & Berger, Phillips Petroleum) . . . How well a 13-ft. distillation column actually works (Gerster & Mizushina, U. Delaware, & Marks & Catanach, Neches Butane Products) . . .

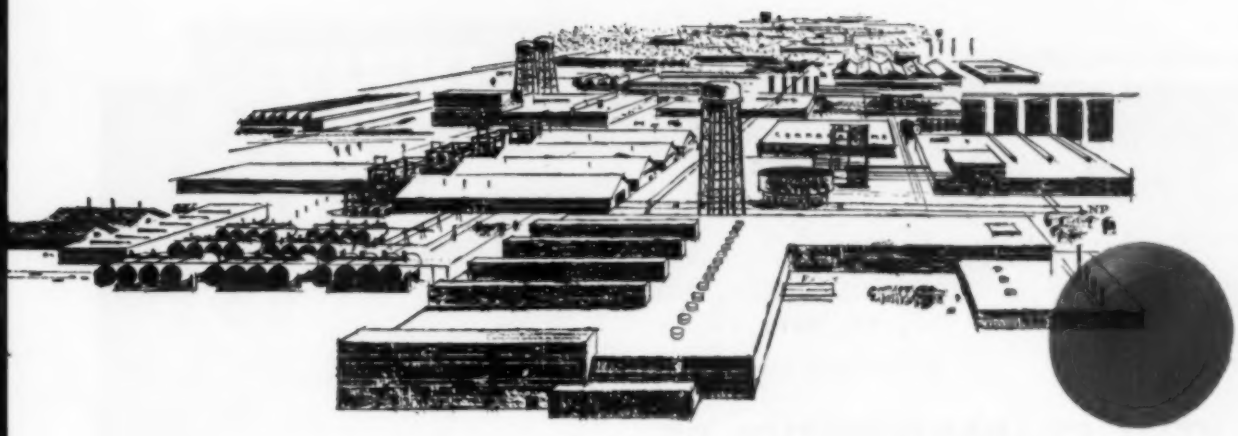
**One way to separate** formerly inseparable mixtures of oxygenated chemicals produced by partial oxygenation of hydrocarbons uses polarity as key (Hopkins & Fritsch, Celanese) . . .

*Next month: Who came to Houston.*

Top row, l. to r.—Ralph H. Price; W. H. C. Simmons; Lloyd E. Brownell; J. L. Franklin (Technical Program Comm. chairman); display of plant tour pictures to influence ticket sales; Ross L. Tedter (mbr., PR Comm.).

Middle—M. W. Putnam; J. O'Shaughnessy; D. W. Oakley; H. J. Lewis (mbr., Hotel & Meeting Rooms Comm.) & Mrs. Lewis; J. R. Barsalou, Mrs. Barsalou (chairman, Hospitality Comm.), A. M. Daley, Mrs. Daley (mbr., Hospitality Comm.).

Bottom—Distillation symposium group: seated, J. W. Clegg, D. E. Berger. Standing, E. D. Oliver, J. A. Gerster, D. E. Holcomb (chairman of symposium—note "Texas gavel"), W. C. Hopkins & M. F. Gautreaux, Jr.; G. P. Monet; Mrs. Alexander, Robert York, W. R. Nisbet, Wayne E. Alexander; Mrs. A. B. Wintringham; G. B. Knight.



# PREVENTIVE MEDICINE

## *for biological warfare...and its peacetime application*

It was early in 1954. Blaw-Knox under contract with the Army Corps of Engineers, quietly completed construction and test operation of the Army Chemical Corps' top priority facility . . . the Pine Bluff Arsenal "production development laboratory."

Here is one of the most complex and top secret projects since the development of the atom bomb. Its purpose? Production and development of biological warfare munitions to strengthen our retaliatory capacity in hopes of preventing another war . . . creation of new antibiotics and vaccines to increase the effectiveness of our immunization against diseases in both war and peacetime . . . experimentation with new means and facilities for detection of diseases and rendering them impotent . . . and accomplishment of these objectives without endangering the plant workers or community.

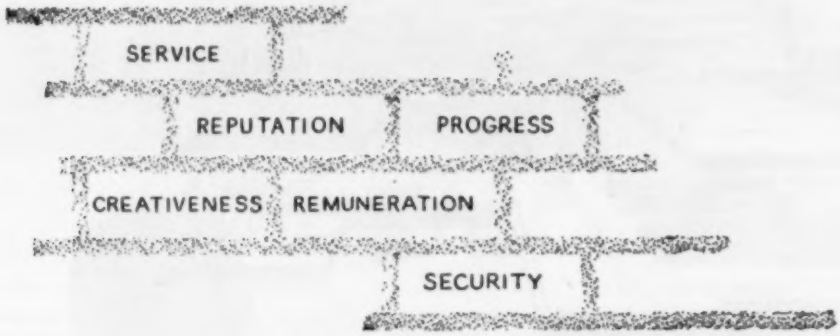
Although information about this facility's operation and production remains highly classified, the story of Blaw-Knox participation now can be told in part.

The Pine Bluff project was a unique experience for the Army Chemical Corps as well as Blaw-Knox. It involved design and construction of special equipment for which no prototypes existed . . . the most exacting leak tests known . . . unusually close mechanical and structural tolerances . . . accurately and automatically controlled temperatures, humidity, ventilation and process cycles. Over a third of its multi-million dollar cost was devoted to an elaborate system of safety devices. In addition to performing all engineering, procurement and complete erection, Blaw-Knox collaborated in initial start-up and testing of this extensive, first-of-its-kind facility.

Our selection for this important project illustrates the faith placed in Blaw-Knox engineering and construction skills, ingenuity and ability to work as a part of the team. When you are in need of a realistic solution to a processing problem and completion of a project on time and within the budget, call upon Blaw-Knox.

BLAW-KNOX COMPANY

*Chemical Plants Division / Pittsburgh 22, Pennsylvania*
*Tulsa 1, Oklahoma/Chicago 1, Illinois/Washington 5, D.C.*




# ESSENTIAL CHARACTERISTICS OF professional conduct

*Arthur K. Doolittle* | Carbide and Carbon Chemicals Company
South Charleston, West Virginia

In 1951 a questionnaire was circulated among the engineering employees of one of America's largest companies. The 1,300 replies that were received showed that the industrial engineer in that company wanted:

1. The opportunity to make progress
2. An adequate salary
3. Creative work
4. A steady job
5. A high professional reputation
6. The chance to be of service to society.

In my opinion the order of listing of these admittedly appropriate desires indicates that the average engineer responding to this particular poll falls a little short of the highest standards of professional conduct.

I would suggest, instead, the following order as more representative of the profesional attitude:

1. The chance to be of service to society
2. A high professional reputation
3. The opportunity to make progress
4. Creative work
5. An adequate salary
6. A steady job.

### Engineering and the Learned Professions

The learned professions–theology, law, and medicine–were founded almost exclusively on the altruistic motive of service to society. Admission to these professions involved a public oath or vow of dedication and their practice required special skills, intellectual attainments, and, generally speaking, a confidential and personal relationship with the client. Standards of conduct established for clergymen, lawyers, and physicians were so lofty that inevitably these practitioners were held in high regard by the public. The professions of theology, law (particularly the judiciary), and medicine are still carried out on a high plane, and their practitioners are accorded full recognition as professionals by the public.

Arthur K. Doolittle

The extent to which engineering may be regarded as a profession is bound to be measured by the degree to which the practice conforms to the standards of conduct established by these three well-recognized professions. Therefore, to maintain general recognition of engineering as a profession, it is important that we understand and exemplify the essential characteristics of deportment established by the original learned professions. In the development of this subject, therefore, I shall indicate what I consider the basic concepts of the professional attitude and why I think that the practice of engineering properly conforms to the same pattern.

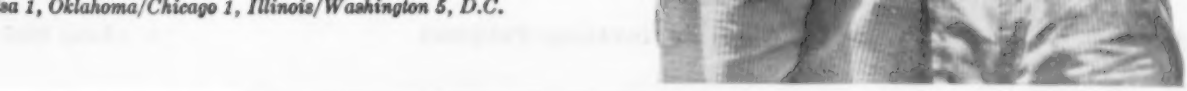
### Basic Concepts of Professional Attitude

1. The most significant characteristic of professional conduct is an awareness of the service motive and a sincere effort to live that philosophy. Although the service motive is recognized as being fundamental to the professions of theology, law, and medicine, it is by no means confined to these groups. Many scientists and engineers are also motivated by high ideals and consciously strive to contribute to, rather than to benefit from, civilization. This determination to be useful to society is, therefore, the first essential characteristic of professional conduct.

2. The acquisition of special skills on a high intellectual level is as typical of engineering as of any of the learned professions. Evaluation of these skills by self-imposed standards presupposes initiative on the part of the individual and implies that a higher degree of competence will be attained than if the evaluation were made by fixed standards, such as routine examinations set up by some public authority.

3. A sense of trusteeship is a third important characteristic of professional conduct. It applies to engineering as fully as it does to the other learned professions. This follows from the fact that the engineer's work is varied and specialized to such an extent that he is placed in a position where his client or employer is completely dependent on him. Ethically, therefore, he has the responsibility to protect his client's or employer's interest.

4. A fourth basic concept of professional conduct is the display of individ-



# VINYL FOAM

FLOW DIAGRAM FOR CONTINUOUS PRODUCTION OF PVC SHEETING

*Vinyl foam is used in this auto arm rest.*

## Another new era of improved products aided by Votator® PROCESSING APPARATUS

Vinyl foam, now out of the pilot plant and into mass production, is bringing important advantages to many products. Here is another great achievement of American industry in which engineers of Girdler's Votator and Thermex Divisions have made vital contributions.

The flow chart shows the basic elements of a system for the continuous production of polyvinyl chloride foam sheeting. This versatile system, in which the Elastomer Process† is widely and advantageously employed, makes possible the use of many resins and plasticizers for the manufacture of open-cell flexible vinyl foam in a broad range of resiliences. It is used for both flat stock and molded articles.

In this system, VOTATOR* Processing Apparatus mixes and cools the vinyl on a continuous basis and delivers it at the right temperature and consistency, ready for spraying or molding.

Many processing functions are performed with VOTATOR Heat Transfer and Mixing Apparatus. Find out how it can help *you* in the development of *new* products and in the *improvement* of existing products. Call our nearest office or write for a copy of the Votator Data Book.

†Licensed by Elastomer Chemical Corporation

*VOTATOR—Trade-Mark Reg. U. S. Pat. Off.

The GIRDLER Company

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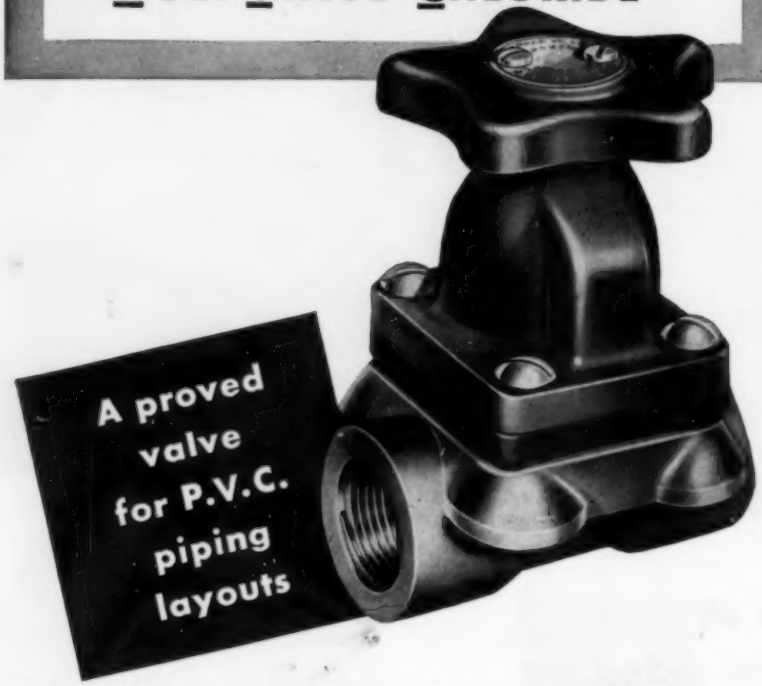
GAS PROCESSES DIVISION: New York, San Francisco. IN CANADA: Girdler Corporation of Canada Limited, Toronto

*Announcing*

**HILLS-McCANNA**

*Saunders Patent*

**DIAPHRAGM VALVES with bodies of POLYVINYL CHLORIDE**




With the addition of valves with unplasticized, rigid polyvinyl chloride (P.V.C.) bodies, Hills-McCanna further expands the most extensive line of corrosion-resistant valves. Now, the corrosion resistance and rugged durability of P.V.C. is available in a valve of proved and accepted design.

Hills-McCanna P.V.C. valves are available in handwheel or lever operated types or with air cylinder, diaphragm motor or electric motor operators for remote or automatic control. Sizes range from ½" through 2". All regular diaphragm materials are available (rubber, Neoprene, Kel-F, Teflon, etc.). Screwed ends are standard. Slip fits available on special order.

Write for further information. HILLS-McCANNA CO., 2438 W. Nelson St., Chicago 18, Ill.

**DESIGN DETAILS**

- Working parts isolated from flow.
- No packing.
- Leaktight under pressure or vacuum.
- Simple pinch clamp closure principle.
- Minimum maintenance even in the severest service.

**HILLS-McCANNA**

*saunders patent diaphragm valves*

**Also manufacturers of**
**Chemical Proportioning Pumps • Force-Feed Lubricators**
**Magnesium Alloy Sand Castings**


## PROFESSIONAL CONDUCT

(*Continued from page* 40)

ual initiative and acceptance of individual responsibility, both of the highest order. It is a little harder to integrate this characteristic with the corresponding situation in theology, law, or medicine because the work of the engineer is not conducted on so intimate and personal a basis as that of the clergyman, lawyer, or physician. Furthermore, it is often more practical for engineers to work in groups or teams in carrying out large engineering enterprises, than to operate individually. Nevertheless, opportunity for display of individual initiative and acceptance of individual responsibility can always be found even in group activity. It is the willingness and desire to do more than just enough to "get by," the urge that drives one to excel that reflects the professional attitude. In this aspect of professional conduct the engineer need bow to no one.

Scientists and engineers are particularly jealous of their professional reputations. The desire to win approval, to have ability recognized, and to gain the confidence and respect of one's associates is a strong motive, particularly among educated people. Although I have not listed the desire for approbation among the four basic concepts of the professional attitude, I nevertheless feel that it represents a strong force in arousing professional consciousness.

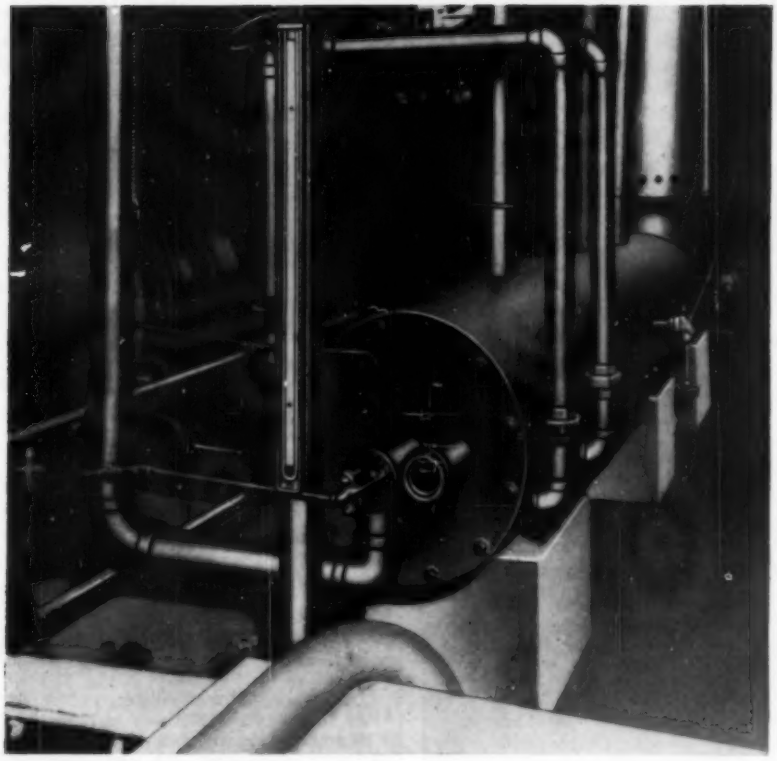
### Maintaining Standards

A primary function of our engineering societies is to set the standards for ethical conduct and for professional achievement and to aid in maintaining these standards. This function is served by giving awards and prizes, by establishing rigid requirements for admission to certain grades of membership in the societies, and especially by continually pursuing programs of accreditation of educational institutions that grant degrees in engineering. Effort is constantly being made through national committees of the engineering societies to encourage professional development of their members and to promote an appropriate recognition, on the part of the public, of the professional character of the engineer's work.

Prestige, however, is something that must be won. It cannot be bought or automatically accorded through affiliation with an organization. It is something that one *commands* but never *demands*. The most that the engineering societies can do is to *encourage* professional achievement. The standing of the profession is enhanced only from the accumulated individual accomplishments of its members.

*Presented at A.I.Ch.E., Houston, Texas, meeting.*

# An Important New Development in Sulphur Burning . . .



Commercial installation of Chemipulp-KC 2½-ton sulphur burner. Note the compact design as compared with conventional burner shown in the background.

## Chemipulp-KC *Jet Type* Sulphur Burner

**More Compact—**
**More Efficient**

**Handles Any Type of Sulphur**

**Long Life—**
**Low Maintenance Costs**

**Fast Start-Up**
**Instant Shut-Down**

In the new Chemipulp-KC Burner the molten sulphur is sprayed into the burner as a fine mist. The secondary heated air is then introduced in several stages, resulting in clean operation and long service life.

Because of the small mass, the burner quickly reaches its maximum efficiency temperature of 2100° F., minimizing the production of $SO_3$. This burner operates efficiently at all $SO_2$ gas concentrations between 12% and 18½%. At its operating temperature of 2100° F. the bitumen in the dark sulphur is completely burned, so that dark sulphur as well as bright sulphur is efficiently burned. Shut-down is instantaneous.

This unusually compact unit is now available in capacities of 1, 2½, 5, 12, 15 and 25 tons per day, and each different size burner operates efficiently at loads of 25% to 150% of rated capacity. Both installation and maintenance costs of this new burner, which is a development of the KIMBERLY-CLARK CORPORATION Research Program, are considerably lower than rotary burners and combustion chambers of equal capacity.

## Chemipulp Process Inc.

**Woolworth Bldg. Watertown, N. Y.**

**Associated with Chemipulp Process Ltd., 403 Crescent Bldg., Montreal**

*Pacific Coast Representative, A. H. Lundberg, 308 Orpheum Bldg., Seattle 1, Wash.*

# Industry Sponsored Conferences

**enlarge the scope of information and experience for men of responsibility in chemical engineering.**

**Esso . . . and**

**International Nickel . . .**

**share practical experience with chemical engineers**

Each year hundreds of industry men and professors from the chemical engineering field attend industry sponsored conferences. Ranging in length from one to three or more days, these serve a highly practical value.

Purpose of the schools is evidently bi-directional. Sponsors expect to benefit, just as do guests. Principal means for accomplishing this is through discussions, in which individual points of view are sought, together with the base of experience and/or reasoning underlying them.

This spring, *C.E.P.* was privileged to attend two of these schools. The first of these meetings was the International Nickel Co. Chemical Group Corrosion Conference at Wrightsville Beach, N. C., April 27-29. The second was the Esso Technology Conference at Bayway Refinery and Esso Research Center at Linden, N. J., May 18-20.

Both had several factors in common. Their groups were small; Inco's 140 and Esso's 28. Both managed to get attendees isolated away from their normal pressures—where they could relax in friendly, comfortable surroundings and have plenty of time for both organized sessions and "bull" sessions. The manner of accomplishment was, however, by quite different techniques. Inco's meeting takes place in a hibernating Atlantic seacoast resort village before the "season" begins. Esso, on the other hand, performs the feat of isolation at the Bayway center—which is well near the center of a major metropolitan area.

Character of attendance varied greatly between the two meetings. Esso was interested in professors; Inco in corrosion technologists. Esso wanted to share some of its technical and other information and experience with the profs, and discuss with them the training given engineering students, their professional development after graduation. Inco wanted to bring its guests—as well as its own staff—up to date on both developments in, and applications experience with, corrosion resistant materials of construction.

Both meetings operated on the basis of predetermined programs made known to the attendees in advance. Both held rigorously to time schedules. The Esso program, coordinated by conference-originator Edward B. Peck, was based primarily on presentations by Esso staff specialists, followed by discussion. Most of the Inco sessions were under the chairmanship of one man, Frank L. La Que, whose extensive ad-lib rapport with corrosion and the personalities working in that field, could keep an informal discussion session running ad infinitum, were it not for the other side of his personality, which keeps a weather eye flicking between clock and printed program. A great deal of Inco session running-time was taken up by visiting specialists.

Esso's program, in brief, was as follows:

Wednesday: A.M.—Assembly, group session on "Operation of a Refinery," coffee, tour of Bayway Refinery. P.M.—Individual could attend one of following group discussions: Operations research; petrochemicals; analytical developments; radiochemistry in the petroleum industry. Evening—Cocktails & dinner, including Esso executives.

Thursday: A.M.—One of following group discussions: Applied mechanics; products research; reaction kinetics and catalytic reactions; operations research. P.M.—Group session on "Case Example of How Various Technical Disciplines Collaborated to Develop the Fluid Hydroforming Process." Evening—Dinner, including alumni of schools represented.

Friday: A.M.—One of the following group discussions: Pumps, compressors and gas turbines; origin of petroleum; radiochemistry in the petroleum industry; petrochemicals. P.M.—General meeting on "Professional development of young technical men."

The tour of the refinery was made in small groups to permit concentration on items of personal interest. Among the facilities visited were the most modern and recently built. At one unit, a modern "pipe-still" facility, the contrast between the orderliness and open access to equipment of the newer unit with an adjacent older one, was severely in favor of the newer. Of particular interest is that Bayway is soon to cease generation of its own steam. A large steam and power generating station being built adjacent to Bayway by a private utility, will upon completion take over the job. This station will burn heavy residual fuel oil from the refinery—will employ a gas turbine for bringing its electric generating equipment into action. When not "on the network," the turbine may serve Esso's development program for low cost turbine fuel.

On the technical session side of the Esso program, the one on operations research will be briefly described as an example.

O. R. originated with military operations. After the war, the methods were applied to large scale industrial manufacturing and marketing operations. At Esso, its principle of use is basically that of ferreting out any and all factors which can or do affect refinery operation and refinery product quality. Specific example given was O. R. analysis of a cat cracker. First, a theory of operation is set up and investigations started to root out key variables. Gradually, revised theory is made to describe the interrelationships of the various major variables mathematically—the result of this is called "model." Later, statistics and other mathematical tools are brought into use (even to the extent of using the IBM computing center in N. Y. C.).

Two lasting impressions stand out: (1) Chemical engineers are engaged in this work at Esso, and (2) the very spirit of O.R. is never-ending inquisitiveness—no matter how good the math and how fast the computor—everyone seemed willing to rush out to the plant for an on-the-spot revision of model, should word come in that a nesting sea gull *might* have caused an irregularity in temperature regulation. . . . .

Turning now to Inco, the program in brief is as follows:

Tuesday: A.M.—Inspection of Harbor Island Laboratory test facilities.

P.M.—Technical session on "Corrosion by cooling waters." Extensive trend towards use of sea-water for cooling noted . . . materials listed for normal and

(*Continued on page* 46)

# LUMMUS

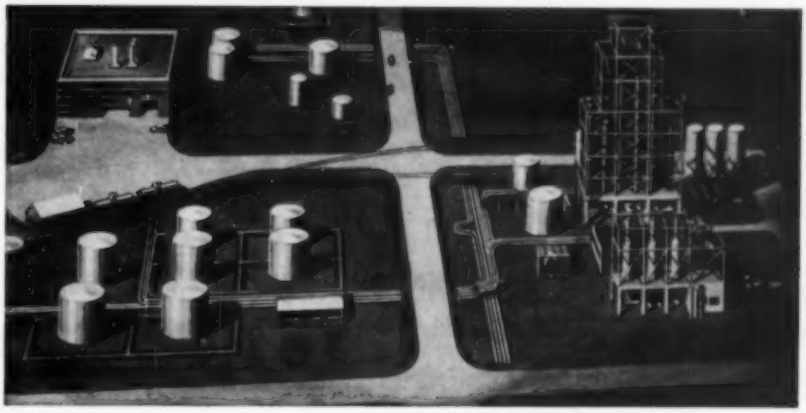
DESIGNING ENGINEERS AND CONSTRUCTORS FOR THE PETROLEUM AND CHEMICAL INDUSTRIES

# LUMMUS TO BUILD AIR REDUCTION CHEMICAL'S VINYL ACETATE PLANT AT CALVERT CITY, KENTUCKY

## Lummus-Built Plant To Come On Stream In Early 1956

The 30,000,000 lb. per year vinyl acetate plant which The Lummus Company is engineering and constructing for Air Reduction Chemical Company, a division of Air Reduction Company, Inc., is a good example of how industry can set up an integrated plant in a strategic location, and insure maximum returns for its capital investment. The plant's attractive location at Calvert City, Kentucky has all the benefits of readily available power, natural gas, water transportation, and a host of related chemical products.

This $3,000,000 installation scheduled for completion early in 1956, is adjacent to the calcium carbide and acetylene plant of Air Reduction's National Carbide Division, and will receive pipeline acetylene from it. The new vinyl acetate plant will be a key development in Air Reduction's chemical expansion which begins with basic raw materials and ends with a variety of products having important commercial and industrial uses.



Vinyl acetate goes principally into polyvinyl acetate emulsions, used in adhesives, latex paints and textile finishes, and polyvinyl alcohol used for adhesives and textile finishes.

At Calvert City, in addition to this new Air Reduction plant, Lummus is also building a $6,000,000 high pressure acetylene derivatives plant for General Aniline & Film Corporation. What better example could be given to show that Lummus is ready, willing and able to design, engineer and construct your next chemical plant.

The Lummus Company, 385 Madison Avenue, New York 17, N. Y. **Engineering & Sales Offices:** New York, Houston, Montreal, London, Paris, The Hague, Bombay. **Sales Offices:** Chicago, Caracas. **Heat Exchanger Plant:** Honesdale, Pa. **Fabricated Piping Plant:** East Chicago, Indiana.

# POSEY FRACTIONATING TOWERS

Fractionating Tower fabricated by Posey Iron Works, Inc. for a large chemical plant in Michigan. 8′ diameter . . . 70′ high . . . ⅜″ skirt . . . ½″ shell and head . . . ⅜″ trays

*Steel plates fabricated by Posey meet all ASME, API-ASME and API codes*

Posey's experience in producing welded steel plate structures dates back to 1910 . . . so Posey has the experience as well as the facilities to design, fabricate and erect almost any type of structure required by the Petroleum Industry. You can trust Posey for refinery structures built to your most rigid specifications. Please write for information or estimates without obligation.

ELEVATED TANKS • HORIZONTAL TANKS • STACKS
PRESSURE VESSELS • DIGESTERS
CARBON STEEL AND ALLOY STEEL PLATE FABRICATION
DREDGE PIPE AND ACCESSORIES

**POSEY IRON WORKS, INC.**

Steel Plate Division Lancaster, Penna.
New York Office: Graybar Bldg. Established Since 1910


**CONFERENCES**

(*Continued from page 44*)

sulfur pollution conditions . . . plus use of galvanic and organic coatings protection, effect of water chlorination . . .

—T.S. on "Cathodic protection" . . . Use in equipment other than heat exchangers . . . use to reduce metallic contamination of products . . . effect of system geometry . . . stray currents . . .

—T.S. on "Protection of fabricated equipment by nickel plating" . . . Electrodeposition vs. electroless processes . . . limits & limitations . . . economics . . . joining methods . . . suitable process environments . . .

—T.S. on "Velocity effects" . . . Discussion centered primarily on seawater for cooling . . . economic vs. corrosion velocity limits in exchangers, piping, valves and pumps . . .

Wednesday: A.M.—T.S's. on "Corrosion by organic acids" and "Corrosion by chlorine & fluorine" . . . emphasized materials, plus effect of concentration, temperature, and extraneous compounds variables . . .

P.M.—T.S. on "Fabrication of nickel & high nickel alloys" . . . Entailed selection of appropriate shop methods . . . welding clad metals, dissimilar metals, over-lays on steel, and cast iron . . . Code construction and other design considerations of process equipment discussed . . .

—T.S. on "Sulfuric acid mixtures" covered materials suited to mixtures containing other acids, and organics.

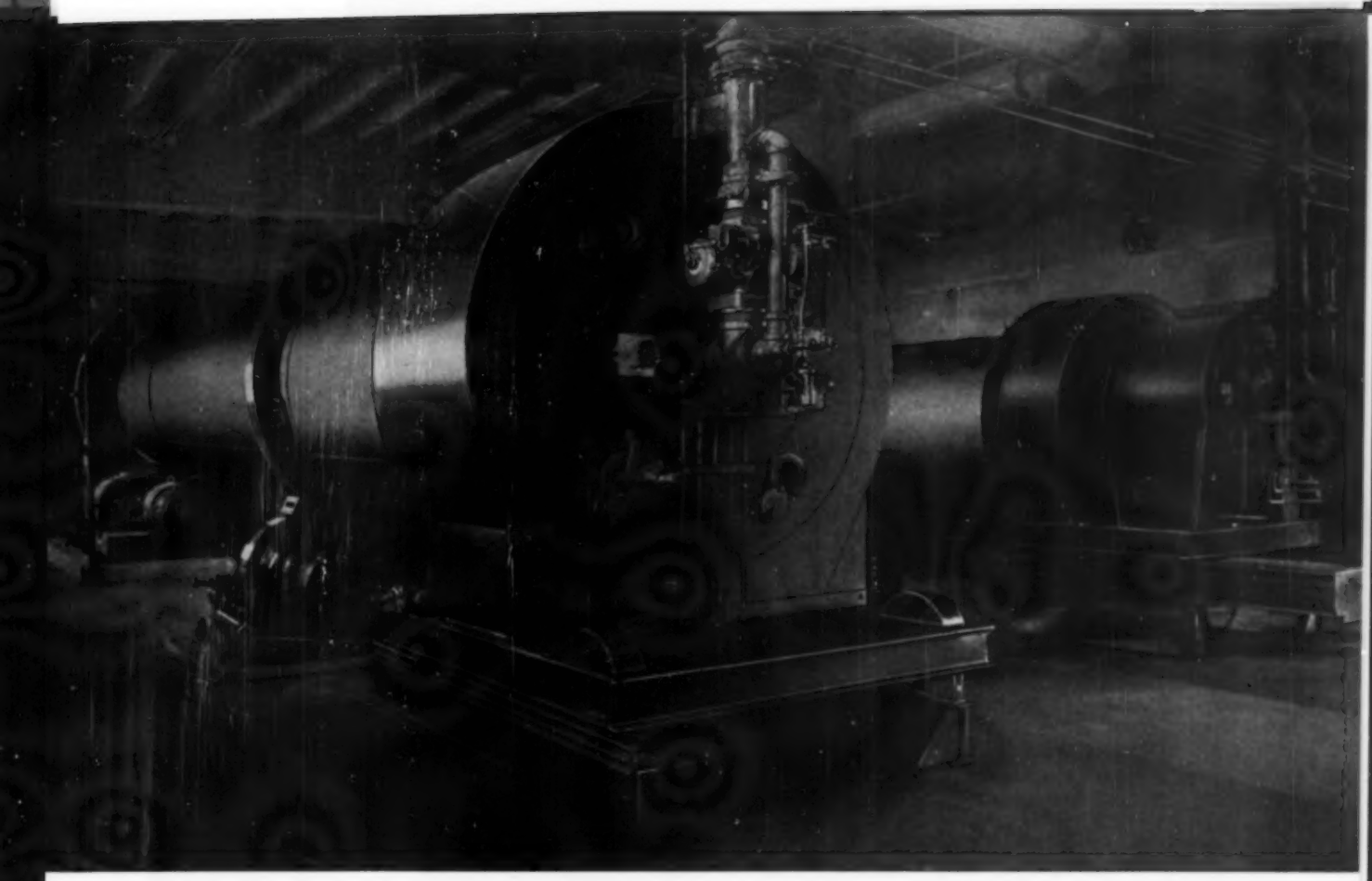
—Dinner, at which guests were made fellows of the Institute of Sea Horses (F.I.S.H.).

Thursday: A.M.—T.S. on "Non-metallic materials & coatings" . . . Included organic materials in different thickness ranges . . . discussed for wide variety of sheets and coatings applications . . . included temperature limitations . . . Inorganic materials discussed similarly . . .

P.M.—Visit to Kure Beach Atmospheric Test Site.

Both Harbor Island Laboratory and the Kure Beach Test Site are operated by Inco not only for its own benefit, but also for others interested in comparative tests for marine atmosphere and seawater corrosion as well as attack by marine organisms. Extensive tests consist of both natural environment and accelerated types, having to do with velocity, alternate flooding and aerating, salt spray, total immersion, and others. Tests are conducted on small samples, high-velocity pipe lines, sizeable centrifugal pumps, standard piling, etc. At the Kure Atmospheric Site, a considerable difference in effect is noted between exposure near to the surf, and that back a few hundred yards; is also a difference at each location depending upon altitude.

Out of the Inco technical sessions came much of the information which provided the basis for the several brief articles on selected corrosion resisting materials appearing elsewhere in this issue.



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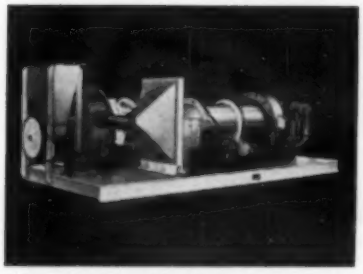

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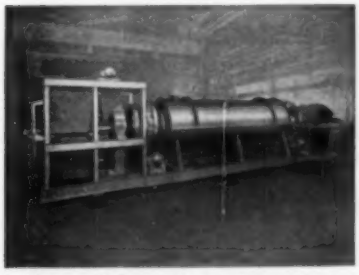

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# ONE DAY MEETINGS

## PHILADELPHIA-WILMINGTON

**Gathering in droves (493), engineers and students listened to an all-day session on "Fluid Flow In Practice" held jointly by the Philadelphia-Wilmington Section and the University of Pennsylvania's School of Chemical Engineering on April 26, on Penn's campus. Emphasis was again on practical know-how based on experience, aimed at the practicing engineer, the aspiring engineer.**

**Highlight of luncheon session: Presentation of annual Zeisberg awards to outstanding chemical engineering students of the area.**

Morning session kicked-off with a review paper given by W. E. Ranz of Penn State. Reviewing the basic relationships of the fluid flow field, Ranz concentrated on the specific field of the flow of liquids and slurries. His paper served as the background for the more specific papers to follow.

New piping systems present many problems to the engineer, problems of the piping itself, and of the relations between the piping and the rest of the plant, said S. A. Gentz, Kellogg. Investment and operating costs are prime factors to be considered in any new piping arrangement. More specific engineering considerations are: space problems, grouping of supports, appearance, directional changes, intersections, and thermal stress.

### Which Valve?

Otto Kneisel, Hammel-Dahl Co., showed that the selection of the proper valve for a system involves two major considerations: Availability of commercial equipment, and service conditions under which the valve is to perform. After these two problems have been solved, the direct engineering factors take over: physical properties of the fluid, safety, standardization, materials of construction, and the basic function of the valve within the process.

Lack of standardization in pumps, led the chemical industry to ask the American Standards Association to sponsor a program leading to centrifugal pump standardization, revealed C. J. B. Mitchell, Du Pont. Matching pump to need is the basic problem with pumps, Mitchell explained. Certain needs cause problems that change the entire requirements for a pump; such as how to move a slurry with a minimum of crystal degradation, or how best to handle a boiling liquid with a centrifugal pump.

l. to r. Schiesser, Trass, Claunch.

### Flowmeter—Which and Why

Louis Gess, Brown Instrument Division, Minneapolis-Honeywell, stressed the recent increase in the price of flowmeters, increase in installation and maintenance costs, as major factors in making proper choice of flowmeter a vital problem. Operation requirements —accuracy, pressure losses, maintenance, and cost of primary elements— are the basic engineering concerns for a proper flowmeter.

In discussing the operation and maintenance of fluid flow equipment in general, N. H. Walton, Atlantic Refining, pointed out that maintenance of pumps depends largely on how the equipment is operated.

Research trends rounded out the session, when A. S. Foust, head of chemical engineering at Lehigh Univ., discussed new problems of the field. Basic point was the fact that new equipment designs are taking us out of the field of research with long, straight, round tubes where fluid properties do not vary widely, into a realm where we must understand the boundary layer theory and hydrodynamics. Higher velocities are leaving the region of simplified concepts behind. There are still fields, said Foust, where our knowledge is limited, data meager.

### Awards

Annual F. C. Zeisberg Memorial Awards were presented at lunch to three leading chemical engineering students. A fourth student received honorable mention.

Presented by the Philadelphia-Wilmington Section to the students of eight colleges and universities in the Section's area who write the best reports for their regular class and laboratory work in chemical engineering, this year's prizes went to: W. E. Schiesser, Lehigh senior, first prize; Olev Trass, Princeton senior, second prize; C. K. Claunch, Jr., Villanova senior, third prize. G. L. Houghton, Delaware Univ., received honorable mention.

Prizes consist of technical books of the winners' own choice. □

## INDUSTRIAL GAS SYMPOSIUM —Five Sections Gather

**Latest developments in the manufacture and use of industrial gases came in for thorough discussion at the Industrial Gas Symposium held by four Ohio Sections and one Western Pennsylvania Section in Columbus on April 29. Top-off for the day, President Barnett F. Dodge, A.I.Ch.E., speaking at luncheon session.**

Covering gases from manufacture, through processes for reforming, purifying, and drying them, to recent advances in industrial gas utilization, the meeting heard seven papers delivered in the two sessions.

Norman Updegraff, Girdler, talked about the manufacture of synthesis gas from natural gas, detailed process, showed recent developments. Taking over on the drying end, R. A. Jones and E. H. Westerland, Linde Air Products, introduced the relatively new drying agent, synthetic molecular sieve zeolites.

Front Row (l. to r.) Zabetakis, Sachsel, Jones, Updegraf, Hann.
Back row (l. to r.) K. S. Jacobs, morning session chmn., Filbert, Baker.

Utilization of tonnage quantities of ozone involves special and difficult engineering problems, according to Victor Hann, Welsbach Corporation. Hann discussed these problems in detail, indicated some methods of overcoming them.

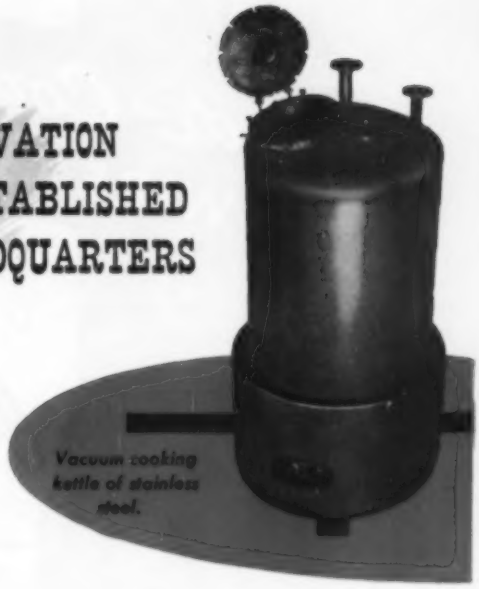
Host Section (Central Ohio), chairman, R. B. Filbert, Jr., and his coworker at Battelle Memorial Institute, G. F. Sachsel, brought the engineers up to date on the use of industrial gas in modern metallurgical process. The program was completed with three more papers: "Hydrocarbon Reforming by a New Pyrolytic Process," G. L. Fleming,



ONE-DAY MEETING

BACK IN THE 1880's

WHEN THE SALVATION ARMY FIRST ESTABLISHED AMERICAN HEADQUARTERS



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## ONE-DAY MEETING

(*Continued from page* 48)

Koppers; "Low Temperature Processes for Industrial Gas Purification," D. F. Baker, Air Products; and "The Prevention of Industrial Gas Explosion Disasters," M. G. Zabetakis and G. W. Jones, Bureau of Mines.

### Dodge at Luncheon

At the luncheon session, Barnett F. Dodge, president of A.I.Ch.E., spoke of his experiences while lecturing abroad in France and Spain. Engineering education and training as we know them in America are virtually non-existent abroad. Teaching methods in these countries still tend to emphasize the accumulation of knowledge rather than the integrated application of that knowledge.

University professors abroad command a great deal more respect, both from their students and the community in general. But their salaries are much lower than ours.

In the evening, Dodge spoke over a local television newscast, commented on the technical manpower shortage. □

L. P. Hammett (l.) presents check to C. W. Arnold; J. M. Church presents certificate.

**A chemical engineer won the first annual award of Phi Lambda Upsilon, national honorary chemical society.** The $500 check and certificate were presented recently to C. W. Arnold, now a research engineer with Humble Oil.

The prize goes each year to the outstanding doctoral candidate in chemistry, chemical engineering, or allied fields. Arnold, 1954 Ph.D. graduate of the Univ. of Texas, won his prize with his dissertation on "A Thermodynamic and Spectroscopic Study of Ethylene Oxide."

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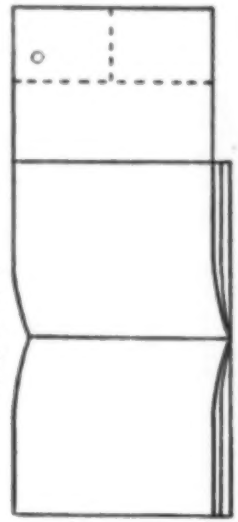

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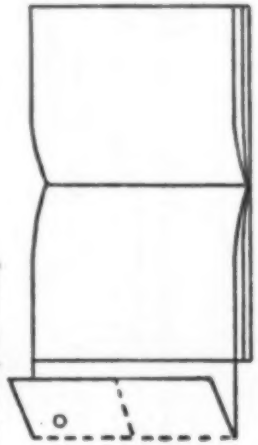

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| 46L | 47A | 49A | 50L | 51A | 52A | 57A | 59A | 61A |
| 63A | 65A | 67A | 68L | 69A | 70L | 71A | 72L | 73R |
| 75R | 76L | 77R | 78L | 79R | 80L | 81R | 82L | 82R |
| 83R | 84L | 84R | 85R | 86L | 86BR | 87R | 88B | 89R |
| 90L | 90R | 91TR | 91BR | 92L | 93L | 93R | 95TR | 95BR |
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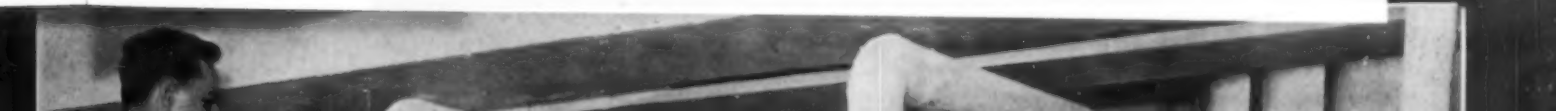


# PRODUCTS (*Continued*)

**57A Vacuum Dryer.** A specially built dryer may solve your problem. Engineering knowledge in field of complete vacuum processing systems available from F. J. Stokes Machine Co.

**59A Flowmeter.** If precise flow measurement is critical in your plant installation of one of these turbine type units will provide high precision. Sizes ⅛ to 6 in. Potter Aeronautical Co.

**61A Filters.** The retractable tank feature of this filter eliminates time loss in breaking connections or outlet seal when opening. Exclusive plate design produces high flow rates. Sparkler Mfg. Co.

**63A Pneumatic Transmitter.** Available in special materials to handle all types of corrosive fluids, units have flexibility of design permitting use of same transmitter chassis for any range of measurements. Republic Flow Meters Co.

**65A Pumps.** Especially designed for use in the chemical process industry. Plunger sizes may be changed to meet change in pressure or capacity requirements. Aldrich Pump Co.

**67A Test Units.** Versatile Beth-Tec test units available. For heating & cooling at elevated temperature levels. Bethlehem Foundry & Machine Co.

**68L Tubular Equipment.** Design, manufacture, maintenance, metallizing services available day or night, Sundays & holidays from Condenser Service & Engineering Co., Inc.

**69A Vacuum Pumps.** Called Chempump unit combines pump & motor in single hermetic unit. Pumped fluid enters rotor chamber. No shaft sealing device required. Chempump Corp.

**70L Process Equipment.** Regardless of the unit required engineers & craftsmen are ready to design & fabricate one. You need only supply performance requirements. Manning & Lewis Engineering Co.

**71A Crystallizers, Evaporators, Filters.** Units have operating profit built in as result of integration of design, engineering, & fabrication. Chicago Bridge & Iron Co.

**72L Heat Exchangers.** Liquid or vapor temperatures always held constant by Niagara balanced wet bulb control method. Automatically varies cooling effect proportionally to load. Niagara Blower Co.

**73R Laboratories.** Research or control laboratories require special planning, design & equipment. Proficiency in this field acquired by years of experience. Consult Wigton-Abbott Corp.

**75R External Bearing Pump.** Called X-B pump has no stuffing box, gaskets, or valves. Capacities 5 gal./min. with 0 to 50 lb./sq.in. discharge pressures. Selection of body block & liner materials. Vanton Pump & Equipment Corp.

**76L Elbows, Tees, etc.** Quikupl stainless steel elbows, tees, couplings, save time, labor, material. Light wall tubing may replace pipe. Only installation tool required is wrench. Cooper Alloy Corp.

**77R cyclOflow Valves.** Introduced for water conditioning service, a 4-position, all-plastic, single control cyclOflow valve for control of ion exchange cycles. American Water Softener Co.

**78L Nickel Alloys.** Castings illustrated made of Duraloy emphasize two items — size & welding operations available. New bulletin gives complete details. Duraloy Co.

**79R Aerofin Coils.** Extended-surface smooth-fin heating & cooling coils make available greater capacity per square foot of face area. Aerofin Corp.

**80L Florite.** This material will selectively adsorb 4 to 20% its weight of water. May be regenerated by heating to 350° F. Floridin Co.

**81R Heat Exchangers.** Long experience with heat exchanger materials make possible enamel-lined tubes to solve set of problems including high temperatures, corrosion, & intermittent operation. Downingtown Iron Works, Inc.

**82L Process Equipment.** Design, development, & fabrication of tanks, piping, special process equipment from corrosion resistant alloys offered by Misco Fabricators, Inc.

**82R Comparators.** Three easy steps all that are required to make pH, chlorine, phosphate or nitrate determinations with these instruments. W. A. Taylor & Co.

**83R Alkyd Resin Installations.** Specialists in construction of alkyd resin plants. Units designed for Dowtherm, electricity, gas or oil heat, constructed in stainless steel. Industrial Process Engineers.

**84L IonXchange.** Varied uses of this process, its flexibility, advantages, other information & aid in solution of individual problems available from Illinois Water Treatment Co.

**84R Jet Mixer.** Particle size is extremely fine when this unit is used. Constructed without vortex complete circulation is assured without foaming. Hermas Machine Co.

**85R Conveyor Dryer.** Drying ranges made available by this equipment provide control & flexibility. Wet-solid materials now handled with speed & efficiency. Proctor & Schwartz, Inc.

**86L Pressure Valves.** New high pressure valves featuring less torque, galling, misalignment, & packing wear, & giving safety, plus material & port size selection available from Pressure Products Industries, Inc.

**86BR Nozzles.** All types of nozzles listed in nozzle catalog from Spray Engineering Co.

**87R Chlorination.** Slime control equipment designed for any need, built for lasting & dependable service. Chlorination increases efficiency & cuts operating costs. Wallace & Tierman.

**88B Plug Valves.** Easy-operating, non-lubricated plug valves for use in many applications. Full range of metals, in sizes ½ to 20 in. either manual, remote, or automatic operation. DeZurik Shower Co.

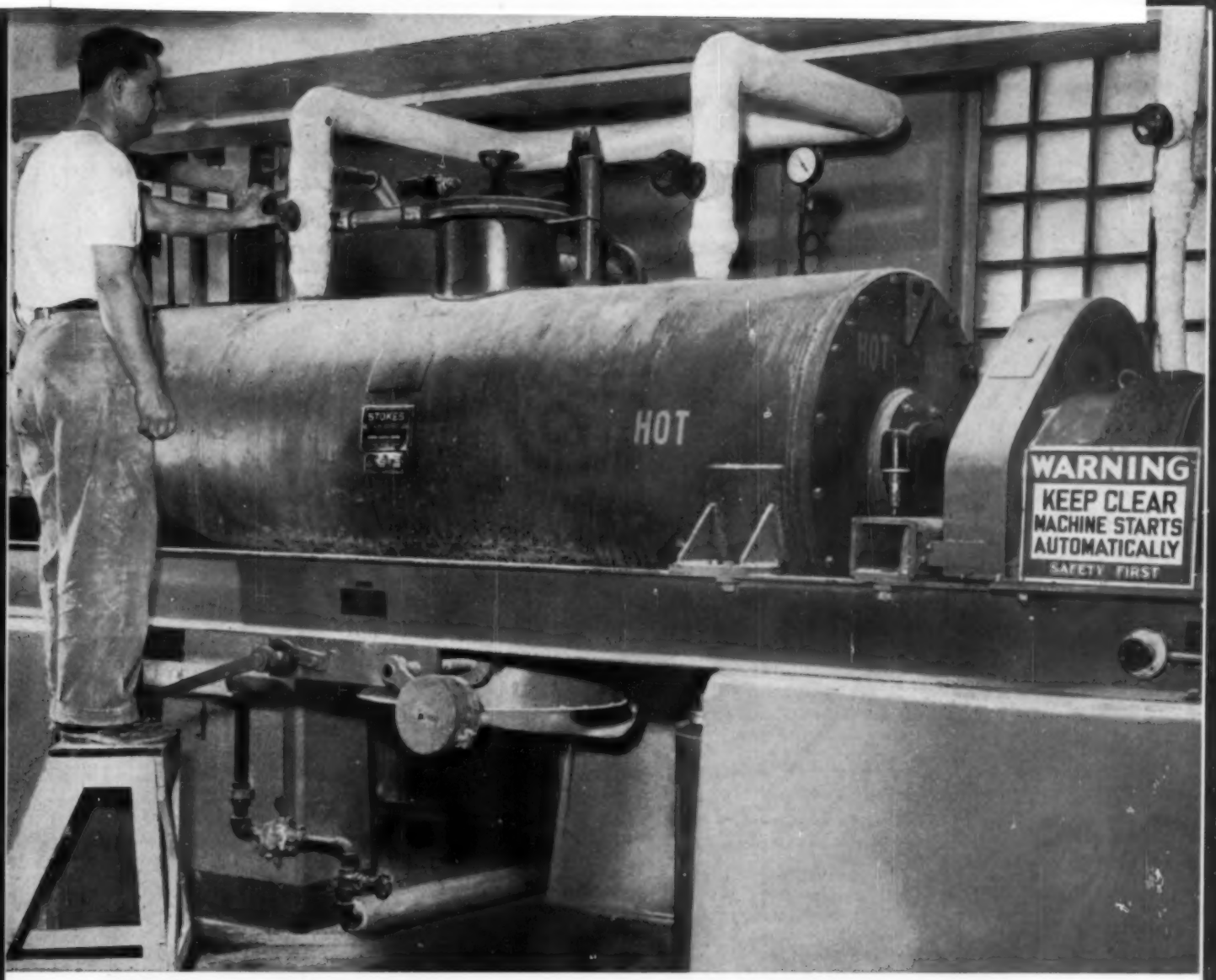
**89R Equipment.** If you want equipment of your own design fabricated by skilled craftsmen to exacting standards in any commercially used metal, send your inquiry to Badger Mfg. Co.

**90L Blender.** A double cone blender with many features. Complete information available from General Machine Co. of New Jersey.

**90R Tower Packing.** Two popular types are Berl saddles & Raschig rings made of Knight-Ware acid-proof stoneware & porcelain. Maurice A. Knight.

**91TR Vaporizers.** Designed to eliminate steam hammer, & minimize freezeup, vaporizers are engineered for durability. Tubes seal welded to avoid loosening of rolling joint. Richard M. Armstrong Co.

(Continued on page 58)




# Weed-killer production problem solved by STOKES vacuum dryer

A leading chemical manufacturer asked us, "What equipment can we use to dry 6 tons per day of a heat-sensitive weed-killer from a true solution containing 67% dissolved solids to a crystalline product of 99.75% solids? Maximum allowable temperature is 50° C and we must crystallize and dry in one operation."

Stokes engineers developed the answer from broad experience with drying problems . . . confirmed it by tests on the chemical in the fully equipped Stokes laboratory . . . recommended a Stokes rotary vacuum dryer sized to give the needed production on a predetermined drying cycle. The unit was purchased and is now on the production line.

This combination of engineering knowledge and laboratory research—the result of 40 years in the design and application of complete vacuum processing systems—is available to all chemical manufacturers. A typical Stokes Rotary Vacuum Dryer is illustrated. Write for informative literature on Stokes Vacuum Drying Equipment, Catalog No. 720, and for the new booklet on Stokes Laboratory facilities, Bulletin No. 640.

F. J. Stokes Machine Company,
Philadelphia 20, Pa.

**STOKES**

# PRODUCTS

(Continued from page 56)

**91BR Compressors.** Units said to save space, up air capacity, cut costs with streamlined, efficient new two-stage, heavy-duty, class HAE angle compressors. Pennsylvania Pump and Compressor Co.

**92L Thermometers.** These instruments ready for immediate delivery. Ranges & immersion lengths for every need. Ace Glass Inc.

**93L Stacks.** Features of Pla-Tank stacks include light weight, ease of installation; fabrication from resin-bonded glass fiber laminate; resistant to wide variety of fumes & temperature. Pla-Tank, Inc.

**93R Filter Paper.** Types for every use in science & industry. May be used alone or with cloth. Special grades available. Eaton-Dikeman Co.

**95TR Filters, Mixers, Tanks.** There's an Alsop unit for every need. Complete range of sizes & capacities custom fitted to your needs. Alsop Engineering Corp.

**95BR Catalyst Supports.** Over two dozen varieties of catalyst supports all highly refractory & inert to most acids. The Carborundum Co.

**96TL Kerodex.** Effective protection against many skin irritants met in industry. Action is like a glove. Does not smear or affect materials handled. Ayerst Laboratories.

**96BL Research Facilities.** When you require "know-how," or if you have technical problems consult Foster D. Snell, Inc.

**96BR Propellers.** Claw propellers of stainless steel will speed production & improve mixing results. Craddock Equipment Co., Inc.

**97TL Turbo-Homoginizer.** For use in preparation of filter aids & pulps for diffusions & extractions. Also high-speed intensive blending & refining of pulps, etc, Gruendler Crusher & Pulverizer Co.

**97R Defoamer.** Increased production without installation of expensive new equipment accomplished by use of silicone defoamer. Two types. Dow Corning Corp.

**97BL Arched Wafers.** A new process & a new service. Arched wafers of your product have advantages over flakes & other shapes. Flakice Corp.

**101TR Process Equipment.** Twenty-five years experience in building of stainless steel, Monel, Inconel, nickel, & aluminum process equipment guarantees satisfaction. Alloy Fabricators.

**101BR Konisampler.** For continuous, accurate dust sampling for permanent records. Employs principle of thermal precipitation. Joseph B. Ficklen, III.

**102TL Meters.** Xacto meters are easily adapted with choice of dials & controls for changing needs to speed liquid handling operations. Provide accurate accounting. Bowser, Inc.

**102BL Bubble Caps.** Bulletin 22 lists 300 styles of bubble caps all furnished without die cost. Reference table on caps & risers gives information for hundreds of variations. Pressed Steel Co.

**103BR Chill-Vactor.** Partial evaporation at high vacuum results in lowering temperature of aqueous solutions to 32° F. Other types producing high vacuums, available. Croll-Reynolds Co., Inc.

**250A Saddle Packing.** Intalox packing makes certain no two pieces can nest or cover each other so that packing surface is rendered ineffective. U. S. Stoneware Co.

**IBC Heat Exchangers.** Brown fintube exchangers so designed as to protect against occupational hazards. Brown Fintube Co.

**OBC Lightnin Mixers.** Newest cost saver for stuffing box repacking is installation of rotary seal easy to replace. Story gives new concept of ease of mixing fluids. Mixing Equipment Co., Inc.

# EQUIPMENT

1 **Mechanical Seal.** An external rotating mechanical seal for pump or agitator shafts, said to last longer under difficult service conditions. Field tested in handling acids, alcohols, alkalies, hydrocarbons, abrasives, & tarry materials. Seal uses balanced bellows design. Bellows fabricated from duPont Teflon. Rotates with shaft. Called Chemiseal part is made in sizes ⅞ to 2⅛ in. United States Gasket Co.

2 **Durcopumps.** Series H in this line are new, heavy duty chemical process pumps designed for continuous operation. Built for high heads & low capacities in addition to routine transfer services. Illustrated folder lists construction details, sizes. Available in Durco corrosion resisting alloys. Duriron Co.

3 **Valves.** The Shear-Seal principle for control of fluids under pressure or vacuum as evolved by Barksdale Valve Co. is demonstrated by a cutout which illustrates how dirt or pipe scale are wiped away & flushed out through a return port because Shear-Seals are said to always maintain intimate contact with the mating surface of the rotor, giving leakproof closure & long service life. Folder.

4 **Plastic Thread Compound.** From Crane Packing Co. a plastic lead seal pipe thread compound packed in polyvinyl plastic tubes. Tube withstands constant squeezing & other forms of severe handling. Compound is Underwriter approved & provides permanent, leakproof seal under many conditions & remains non-hardening which permits easy disassembly even after years. Withstands pressures to 6,000 lb./sq. in.; temperatures to 600° F.; insoluble in most mediums.

5 **Reflux Heads.** Improved automatic distillation reflux heads from Distillation Engineering Co. for high vacuum, pressure & temperature, or for corrosive & hazardous service. Simple, accurate & dependable operation eliminate reflux control problems. Folder shows schematic diagrams. Standard sizes 2 to 36 in. diam. Larger sizes available. Made of carbon steel with stainless steel internals. Supplied in alloy construction if desired.

6 **Heat Exchangers.** Falls Industries, Inc. announce line of Impervite unitized pumping heat exchangers. Unit is a completely factory fabricated piece of equipment ready for immediate operation. Called Impervite Pumping-X-Changer. Can be made portable, an advantageous feature in pharmaceutical & pilot plants, or any small batch operation. Used in combination with Impervite centrifugal pumps to 200 gal./min. at 100 ft. head.

7 **Filter Cartridges.** Developed by Hilliard Corp. filter cartridges types F-718 & FW-718 to meet need of large filter area, low pressure drop, & high dirt storage capacity. Fabricated from cellulose cartridges are suitable for filtering straight mineral oil or heavy duty

(Continued on page 60)

OUT
IN
wherever precise flow
measurement is critical . . .
Potter TURBINE TYPE FLOWMETER
ACCURATE, DEPENDABLE POTTER FLOWMETERS are being specified by more and more chemical processors each year for jobs that demand high reliability, high precision, low maintenance, extreme control precision. Available in sizes from ⅛" to 6" units, they measure caustics, acids, corrosives, unstable compounds, suspensions, super-refined liquids and other hard-to-handle liquids at temperatures up to 1200°F and at pressures to 35,000 psi. Easily incorporated into complex control systems because of their linear output, Potter sensing units produce a signal that can be telemetered, fed into digital information handling systems, or measured directly to indicate or control flow rate or total flow.
Find out how this unique approach to flow measurement can help solve your flow-control problems. Write for Bulletin S-1.
POTTER AERONAUTICAL COMPANY • Route 22 • Union, N. J. • Phone MUrdock 6-3010
Makers of "Potter Engineered" products

# EQUIPMENT

(Continued from page 58)

detergent oils without removal of detergents & oxidation inhibitors. Density of filter paper results in removal of particles down to 5 microns.

8 **Variable Speed Pulley.** Ratios up to 3:1 at 7½ to 15 H.P. now available with new variable speed pulley easily installed on new or old equipment. Finger-tip pressure changes speed while machinery is in motion. Used in conjunction with 1,750 rev./min. motor. Standard bores are 1¼ to 1⅝ in. Lovejoy Flexible Coupling Co.

9 **Float Valve.** Liquid level control in many industrial operations achieved by use of new float type valve from Robertshaw-Fulton Controls Co. For use in air conditioning installations, power plants, chemical plants, etc. Constructed mainly of bronze & steel. Floats of other metals available. Eleven valve sizes available from ¼ to 4 in. Larger sizes supplied with semi-balanced, double-seated valve.

10 **High Pressure Valve.** Now available a 60,000 lb./sq.in. valve from Autoclave Engineers, Inc. Research engineers & chemists will be interested in eight improved design features. Complete information set forth in available bulletin.

11 **Density Gauge.** Per cent by weight of solids or liquids slurries now may be easily measured & controlled by use of this series of gagues. All measuring components located external to pipe or vessel containing slurry. Thus agglomeration & abrasive conditions encountered do not interfere with operation of gauge. Ohmart Corp.

12 **Ball Bearing Units.** Two bolt flange ball bearing units interchangeable with four bolt units. Available in shaft sizes ½ to 3/16 in. Unit retains all Sealmaster patented design features. Leaflet. Stephens-Adamson Mfg. Co.

14 **Flame Photometer.** Brochure on operation of Model 146 flame photometer for analysis of alkali metals in solution, published by Perkin-Elmer Corp. Several new features include internal standard control equipment, quick-setting element selector, atomizer-burner assembly. Specifications include ranges for. sodium, potassium, other alkali earth metals.

15 **Pressure Pilot.** Featuring self-contained design, pressure pilot has integral gauge for process pressure indication. Provides direct setting of control point on same calibrated gauge dial. Aiuminum case is 8½ x 8½ x 3¼ in. with all connections on left side rear. Can be surface, flush, or valve mounted. Hammel–Dahl Co.

16 **Radiation-Shielding Windows.** Completely assembled windows for nuclear research uses available from Corning Glass Works. Consist of individual castings of radiation-resisting glass to 10 in. thick, stacked together in a framework. Units are shipped ready for installation in test cell walls. Reduce radiation intensity to tolerable level, permit direct observation of work carried out in hot areas. Glass densities 2.7 to 6.2 used.

17 **Fire Walls.** Now offered by Virginia Metal Products Corp. an Underwriters' approved one-hour movable steel partition called Mobil Fire Wall. Folder shows diagrams, gives description, test requirements, available sizes, other data.

18 **Explosion-Proof Meter.** Available from Buffalo Meter Co. a liquid meter with explosion-proof electric contact. Shuts off pump after desired amounts are delivered or for signaling operator. For use in hazardous atmospheres. Consists of standard Niagara meter plus register containing electric switch. Wide variety of register constructions offered & described in special bulletin.

19 **Recording Spectrophotometer.** Based on Beckman Instruments, Inc. DU quartz monochromator new model recording spectrophotometer. Range of 200 millimicrons to 3 microns plus recording linear in transmittance, linear in absorbance or direct in energy. Built-in recorder presents data on file-size preprinted chart paper. Variety of absorption cells available.

20 **d/p Cell Transmitter.** Said to be major advance in design a force balance flow transmitter from Foxboro Co. Weighs 21 lb.; compact for close coupling to orifice flanges. Continuous adjustment over entire range 0 to 50 in. to 0 to 250 in. of water differential without change of parts. Also new are overrange stops for protection to fill 1,500 lb./sq.in. rating of instrument.

21 **Fog Nozzles.** Bete Fog Nozzles, Inc. announces series N Tu-Cone nozzles. High resistance to clogging, simple design, long reach of fog pattern & uniform atomization. Employs two spiral turns producing inner & outer cone resulting in uniform coverage over 90 degree cone. Made from one piece of ⅞ in. hex metal with no internal parts.

22 **Control Valves.** Control valves for NAK & similar molten metal services. Body rating of line is 150 lb./sq.in. at 1,600° F. Available in body sizes ½ through 6 in. with Domotor, cylinder or manual operators. Variety of end connections. Annin Co.

23 **Tower Packing.** Based on principle of interstitial holdup new polyethylene tower packing said to give increased efficiency, capacity, is lighter in weight, forms unbreakable units, etc. Folder from Harshaw Chemical Co.

24 **Sealed Motor-Pumps.** Three hermetically sealed motor pumps will handle radioactive water with zero leakage in capacities 5 to 17,000 gal./min. Special designs available for handling liquid metal at system temperatures to 1,000° F. Parts contacting pumped fluid made of corrosion resistant alloys. No external shaft seals. Discharge nozzles designed to be welded into pipeline. Westinghouse Electric Corp.

25 **Control Valves.** Flanged valves for handling corrosive materials & abrasive slurries, wet or dry, are of straight-through flow pinch type. Consist of flanged rubber body & self-supported air-operated pinching mechanism. Give bubble-tight shutoff, have either positioner or flow control, or without positioner as desired. Bulletin shows schematic diagrams, tables, other information. R. K. L. Valve & Mfg. Co.

26 **Evaporator.** Operation of the Lo-Temp evaporator is subject of bulletin from Mojonnier Bros. Co. Developed for the citrus industry, now used by dairy, pharmaceutical, other industries. Four-color schematic diagram shows operation. Other photographs, listing of models, other information given.

27 **Balance Indicator.** A thermo electric manual-balance indicator announced by Thermo Electric Co., Inc. Makes null balance measurements for applications where speed of self-balancing indicator not required. Useful for direct reading of temperature differences by use of two resistance bulbs connected, opposed to each other, to the same indicator. Measures differences as small as 0.02° F. Accuracy to ±¼ of 1% of scale.

(Continued on page 62)



(Continued from page 60)

# buy quality

## ...in a filter

# buy Sparkler

## ...and collect cash dividends in labor savings and operating economies

This Sparkler MCR rectractable tank filter is saving $24,000.00 a year in labor alone for a large mid-west brewery. Every installation of this filter has resulted in lower cost filtering.

The retractable tank idea eliminates the time wasted in breaking pipe connections or outlet seal in opening filter. Fast manipulation with resulting labor saving is a distinctive feature of the MCR filter.

The smooth hydraulic power mechanism simplifies controls to practically a push button operation.

The exclusive Sparkler MCR plate design produces exceptionally high flow rates with unmatched durability.

When you buy a Sparkler MCR retractable tank filter, and see it operate, you have that comfortable assurance you have the best, and most economical, in a heavy duty filter.

10 sq. ft. MCR Models available for sample testing.

Mail coupon for details today
or phone at our expense.

**Sparkler Manufacturing Company**
**Mundelein, Illinois** Phone: Mundelein 6-6430

Manufacturing plants in Canada, Holland, Italy, Australia.
Service representatives in principal cities throughout the world.

**SPARKLER MANUFACTURING COMPANY**
**Mundelein, Illinois**

☐ Send literature on MCR retractable tank filters.
☐ Would like to see representative engineer about our filtering problem.

Individual_____

Company_____

Address_____

(Continued from page 60)

# CHEMICALS

40 **Nylon Powder.** Described in bulletin a chemically treated nylon powder for cold pressing & sintering from National Polymer Products, Inc. Considers both established & prospective applications from company's Nylasint formations. Detailed information on physical & chemical properties, along with characteristics it imparts. Role as a suspending agent & effects of filler additions also discussed.

41 **Chloromethanes.** Data on diverse uses & physical & chemical properties of chloromethanes — methylene chloride, methyl chloride, chloroform, & carbon tetrachloride in booklet from Solvay Process Div., Allied Chemical & Dye Corp. In addition to general data applying to chloromethanes, sections that supply specific figures & information on each product.

42 **Curing Agent.** Shell Chemical Corp. announces development of a new liquid curing agent, Epon Curing Agent Z, for use with epoxy resins. Combines ease of handling conventional liquid polyamines with good performance characteristics of solid polyamine curing agents. Use simplifies handling, eliminates heating-in usually required. Liquid of approximately 2,000 cps. viscosity.

43 **Molybdenum Pentachloride.** Bulletin gives more important physical & chemical properties of chemically pure material. Also describes preparation. Climax Molybdenum Co.

44 **Vinyl Plastisol Resin.** Technical data on properties of material, plus compounding & application of Opalon 410 contained in 22-page report available from Monsanto Chemical Co. Book illustrated with charts & graphs describes effect of plastisol ingredients on finished compound.

45 **Solvent.** Known as Ketol solvent 75, a mixture of acetophenone & phenyl methyl carbinol, material is described in technical bulletin from Carbide & Carbon Chemicals Co. Said to be an excellent dye carrier for Dacron polyester fibers & blends of these fibers with wool & viscose. Promotes uniform dyeings at temperatures as low as 180° F.

46 **Amine Curing Agent.** A modified curing agent called Experimental Curing Agent U now announced by Shell Chemical Corp. Development work shows substance to be useful in epoxy castings, potting & adhesives, & laminating applications where room or moderately elevated temperatures of curing are desired. Expected to find wide use with lower molecular weight resins especially Epon 828. Can be used with all Epon resins.

47 **Ethyl Benzene.** Technical information on ethyl benzene available in data sheet from Carbide & Carbon Chemicals Co. Physical properties specifications, reactions, included.

48 **Barium Products.** Westvaco Mineral Products Div. make available a handbook on barium products. Loose leaf, it contains 24 pages of illustrations & information. Said to be the first of its kind on this subject.

49 **Activated Carbon.** Use of activated carbon either as a catalyst or a catalyst support in many chemical processes is the subject of technical bulletin No. 20, from Barneby-Cheney Co. Covers particle sizes, chemical & physical properties, special high-activity advantages, plus specifications of numerous types of extra-hard granular & powdered Adsorbite activated carbons.

# BULLETINS

51 **Jet Vacuum Pumps.** High vacuum gas handling without moving parts are feature of single stage steam jet vacuum pumps described in bulletin from Schutte and Koerting Co. Considered are application, construction, operation of equipment. Also performance data & sizing tables. Air load capacities from 1.7 to 8,650 lb./hr. For use in filtration, distillation, mixing, heating, vacuum transfer, as well as vacuum packaging in food industry.

52 **Flow Meters.** Bulletin from Bailey Meter Co. on open channel flow meters for measurement of liquids containing suspended solids for water supply & waste treatment applications in chemical process plants. Well illustrated, shows schematic diagrams, lists applications, other data.

53 **PVC Valve & Fittings.** A comprehensive, well-illustrated circular from Lunkenheimer Co. on Luncor PVC Pipe & Fittings. Said to have good corrosion resistance to most chemicals. Exclusive process said to give exceptional strength to products. Enlarged cutaway view. For chemical, atomic energy, paper & pulp, many other industries.

54 **Shut-Off Valves.** Automatic shut-off valves for protection of gauges & instruments in hydraulic or pneumatic systems against overloads, considered in bulletin from Sprague Engineering & Sales Corp. Several sizes for pressures from 10 to 5,000 lb./sq. in. Includes features, specifications, & complete adjustment & installation details.

55 **Alloy Equipment.** Complete design & fabrication facilities of alloy equipment offered by E. C. Wolferz Alloy Equipment. Fabricators on stainless steel, nickel, Monel, Inconel, Everdur, aluminum, carbon, solid & clad steels. Folder shows typical units.

56 **Quantometer.** An X-ray industrial quantometer from Applied Research Laboratories. A new tool for chemical analysis & specifically designed for production control applications. Folder includes technical description, specifications, illustrations. Uses multi-channel concept.

57 **Agitation & Blowing.** Spencer Turbine Co. turbo-compressors for agitation & blowing of acid tanks, chemicals, ice tanks, & others discussed in illustrated folder. Said to give high efficiency at low maintenance cost.

58 **Industrial Controls.** Said to be most complete catalog ever published by General Controls Co., now available. Covers broad line of automatic industrial controls & gives necessary information about each item. Includes electrically operated valves for gas, air, oil, water, steam, other fluids, in various applications.

59 **Valves.** Choice of the right valve made easy by use of bulletin from Crane Co. Covers three principal types, names of valve parts, variations to be considered, materials of fabrication, etc. Well illustrated, gives cutaway diagrams, specific information on each item.

60 **Vinyl Resin Coating.** Called Amercoat No. 87 this vinyl mastic is a heavy bodied, high solids, vinyl resin coating applicable in thicknesses to ten mils in one coat. Leaflet covers general chemical, & physical properties. Application instructions include alternate procedure of hot spray. Amercoat Corp.

61 **Refineries.** All phases of design & erection of petroleum refineries is subject of current issue of "Kelloggram" published for petroleum & chemical industries by M. W. Kellogg Co. Well illustrated, also shows cross-section diagrams.

(Continued on page 64)

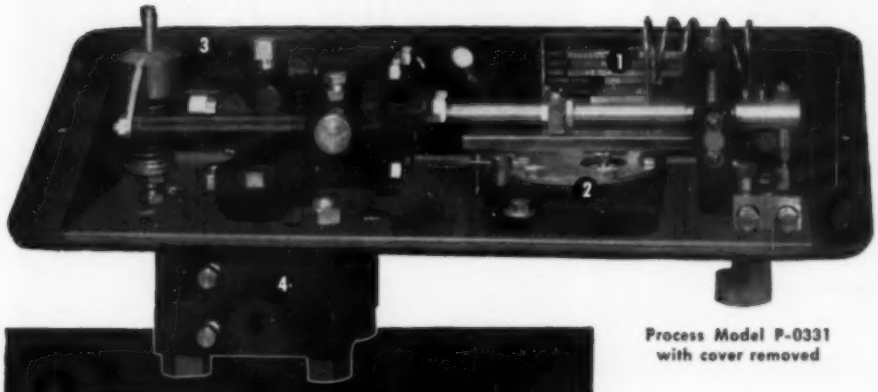
**PROCESS CHANGES CAN'T OBSOLETE THIS TRANSMITTER . . .**

**❶ 10-1 RANGE CHANGE —NO CHANGE OF PARTS**

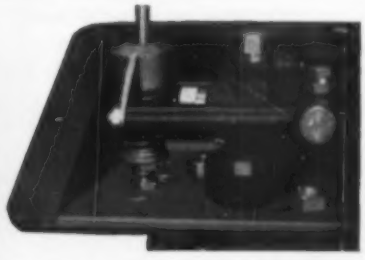
Double weighbeam construction on many models permits range changes as much as 10-1, just by turning a set of locking nuts to change a fulcrum point.

**❷ ADDITIONAL 16-1 RANGE CHANGE—STILL NO PARTS CHANGE**

Range may be changed on all models by loosening retaining bolts and sliding the reaction chamber to a new leverage position. Reaction area may be changed for further range change.




Process Model P-0331 with cover removed



**❸ SUPPRESS, COMPOUND OR REVERSE RANGES**

Balancing spring, installed to exert either an upward or downward force on transmitter weighbeam, quickly converts transmitter for range suppressions up to 80% of total range, for reversed ranges or for compound ranges where pressure fluctuates above and below atmospheric pressure.

**❹ MAJOR RANGE CHANGES**

Range change plates may be easily inserted or removed from measuring chamber to change the effective diaphragm area for major range changes. Similar plates may be used also in the reaction chamber for further range change.

# REPUBLIC PNEUMATIC TRANSMITTER with EASY RANGE CHANGE

Here's the pneumatic transmitter for measuring differential, flow, pressure or level that saves you time and money when operating conditions are not definitely known or processes are likely to be changed. Extreme flexibility of design lets you adapt the same transmitter chassis for almost any range of measurements—often without any change of parts.

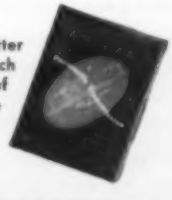
Process Model pictured above has a differential range of 0-12″ $H_2O$ minimum and 0-880″ $H_2O$ maximum at operating pressures to 1500 psig. Other models are available for differential ranges as low as 0-0.6 $H_2O$ or as high as 0-750 psi.

Transmitters may be constructed of special materials to handle almost all types of corrosive fluids. Ruggedly built, they give long service out-of-doors. Accuracy is guaranteed at ½% of full range on standard models.

Republic transmitters are used in process, chemical and petroleum plants all over the country. Investigate their advantages for your plant.

***FREE DATA BOOK***

Get the full story about Republic transmitter flexibility. Send for free Data Book which gives all the facts about complete line of Republic transmitters, including Square Root Extracting and Pneumatic Electric models.



**REPUBLIC FLOW METERS CO.**

2240 Diversey Parkway, Chicago 47, Illinois

# BULLETINS

(Continued from page 62)

62 **Plant Specialists.** A well illustrated catalog from Singmaster & Breyer describes their services as consultants & as designers, constructors, operators, & managers of various types of plants.

63 **Bradmills.** Binder insert folder from Pennsylvania Crusher Co. on bradmills for impact reduction of chemical solids & metallurgical materials to cubical particles. General description given with photographs & diagrams. Deliver 100% sized material. All material screened before delivery.

64 **Temperature Regulators.** Self-contained temperature regulators are subject of bulletin from Leslie Co. Three basic designs. Information on selection, specifying, ordering. Quick reference table, pressure-temperature ranges, cutaway views.

65 **Ejectors.** Steam jet air ejectors for modern low-cost air removal from condensers. Leaflet describes principle of operation, considers ejector classification, inter-after condensers, steam jets for special services. Tables, photos, cutaway view. Condenser Service & Engineering Co., Inc.

66 **Electron Microscope.** Bulletin from Radio Corporation of America on two types of electron microscopes. Features high resolution, insensitivity to vibration & magnetic fields, conveniently located controls, with all components easily accessible. Said to be practical research tools for science & industry.

67 **Spectrophotometer Recorder.** For use in both research & control the Spectracord recorder supplies rapid & automatic qualitative & quantitative analyses, gives high resolution continuous spectra in 90 seconds each, records flame, fluorescent & other emission spectra. Well illustrated catalog in addition to other features shows a reproduction of actual chart recording. Warren Electronics, Inc.

68 **Stainless Tubing & Pipe.** Comprehensive catalog from Carpenter Steel Co. covers the fabrication & working data for Carpenter stainless tubing & pipe. Sections on annealing, beading, bending, expanding, soldering, welding, & other phases of treatment, plus charts, illustrations, other data.

69 **Filter Presses.** Better filtration is the subject of a new catalog from T. Shriver & So., Inc. Gives details of their presses, plus advantages of filter presses, how to select them, types of plates & frames, washing filter cake, also tables, illustrations, etc.

70 **Automatic Controls.** A well organized loose leaf binder from Automatic Temperature Control Co., Inc. on the subject of all types of automatic control systems. Concerns itself with design, construction, startup & other phases of the subject. Case histories presented with description of scope of ATC Co.

71 **Vertical Pumps.** Johnston Pump Co. folder concerns a vertical turbine pump for use with volatile fluids. Cutaway views of various types with detailed information on design advantages & other pertinent facts.

72 **Ni-Resist.** A 63-page catalog from International Nickel Co., Inc. deals with engineering properties & applications of Ni-Resist a corrosion resistant, nickel-alloyed cast iron in nine specific industries, also general uses. Tabulation of mechanical & physical properties offered by eight types of the material. Lists superiority over gray cast iron under 400 industrial conditions.

73 **Refractory-Fiber Felt.** Material developed for high temperature uses & called Thermoflux is used as thermal insulation, sound control, refractory packing, filtration, etc. Withstands continuous exposure to 2,000° F. Folder gives details on sound absorption coefficients, plus a thermal conductivity table. Johns-Manville.

74 **Stainless Steel Products.** Reference Book No. 56 from Schnitzer Alloy Products Co. illustrates all the many products in their line gives all details on each. Includes angles, chains, gauges, various valves, washers, wire, as well as many others.

75 **Pneumatic Receiver Gauges.** From United States Gauge Div. of American Machine & Metals, Inc., catalog on their pneumatic receiver gauges. Used to indicate pressure, temperature, flow, other variables transmitted by air pressure. Dial sizes 2½ to 8½ in. Construction of various types discussed, other details given.

76 **Marketing & Research.** Answers to many of the questions involved in marketing & economic research are set forth in a bulletin from Foster D. Snell, Inc. specialists in the field.

77 **Compressed Air Tools.** Making your air compressor capacity effective depends upon compressed air tools. Bulletin from Sarco Co., Inc. covers their line of air compressor tools & tells how they can be effectively utilized. Also describes drain traps, electric thermostats & pressure switches.

78 **Aerosol & Smoke Photometer.** A portable indicating-recording instrument from Phoenix Precision Instrument Co. described in folder. Features, typical applications, information on each type. Facilities & personnel of company available for consultation, engineering, research, design, & manufacture of new instruments & systems.

79 **Adhesives.** Revised edition of "How to Handle Adhesives for Transparent Films," now available from National Adhesives, Div. National Starch Products Inc. Shows completely new chart describing properties & characteristics of all principal types of transparent film including Mylar, cellophane, pliofilm, polyethylene, cellulose acetate.

80 **Nuclear Reactor Controls.** "Control Systems for Nuclear Reactors," published by Leeds & Northrup Co. outlines design, instrumentation, & fabrication of complete package control systems for operation of any type research or power reactor. Explains control channels which comprise reactor control system, plus other pertinent data.

81 **Centrifugal Pumps.** Self-priming centrifugal pumps for use in the chemical industries & available from Lawrence Pumps, Inc. discussed in folder. Differ from standard design in that pump casing or volute is made with two discharge ports located approximately 120° with respect to each other. No valves required in operation of pump. Only need is to fill suction chamber & pump casing with liquid when pump is first started.

82 **Synthetic Ammonia Plants.** How flexibility may be obtained in plant design for production of synthetic ammonia is subject of 12-page booklet from M. W. Kellogg Co. Describes four basic plant types for generation of synthesis gas to suit local conditions & types of feed materials. Much other detailed information.

83 **Chemical Pumps.** Custom built chemical pumps engineered to your demands available from Byron Jackson Co. Feature quick, easy dismantling, all parts interchangeable except pump case & impeller. Four different pump sizes may be used on one basic stuffingbox & bearing bracket assembly. Illustrated folder includes selection tables & performance charts.



Now—CRACK-FREE CHROMIUM

ing factor, is slower for Crack-free than

# Why ALDRICH PUMPS Reduce Maintenance Cost

ALDRICH

*Write for catalogs, engineering service or a representative's call. We invite your inquiries.*

**Design simplicity . . . rugged construction**

Aldrich Pumps are built to take punishing service year after year. You can find Aldrich Pumps, today, in good running order after 30, 40 and even 50 years of service. Durability such as this is the result of Aldrich's design simplicity and rugged construction.

**Accessibility . . . sectionalization**

When wearing parts are due for replacement, in Aldrich Pumps they can be replaced easily, quickly and at low cost. For instance, manifolds can be moved out on the holding studs and you can lift out and replace valves as complete units. . . . Stuffing boxes are particularly accessible—making it easy to renew packing. . . . To meet a change in pressure or capacity requirements, plunger sizes can be changed — in most cases merely by using new glands, throat bushings and packing in the same fluid-end. . . . Wearing parts are interchangeable among pumps of the same stroke size. . . . Fluid-ends are sectionalized to make possible low cost parts replacement and can be made of stainless steel, bronze, Monel or other material.

**TYPICAL CHEMICAL APPLICATIONS FOR ALDRICH PUMPS:**

| | |
|---|---|
| caustic solutions | fatty acids |
| anhydrous ammonia | nitric acid |
| amine solution | cobalt solutions |
| pulp density mineral ore | acetic acid |
| aqua ammonia | gritty water |
| slurry nickel catalyst | urea |

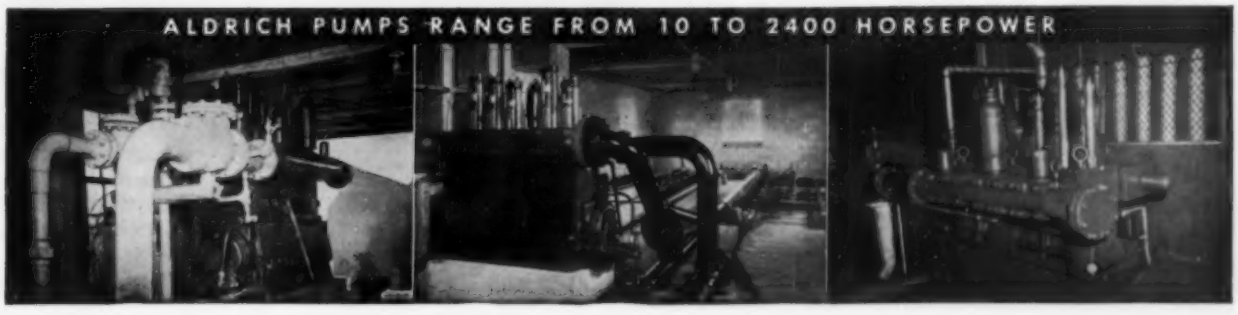
. . . as well as liquids encountered in petroleum refining, petrochemical and other industries . . . corrosive liquids, high viscosity, and/or high pressure applications.

*Representatives in Principal Cities*

**The Aldrich Pump Company**

20 Gordon Street • Allentown • Pennsylvania

ALDRICH PUMPS RANGE FROM 10 TO 2400 HORSEPOWER



# Now—CRACK-FREE CHROMIUM

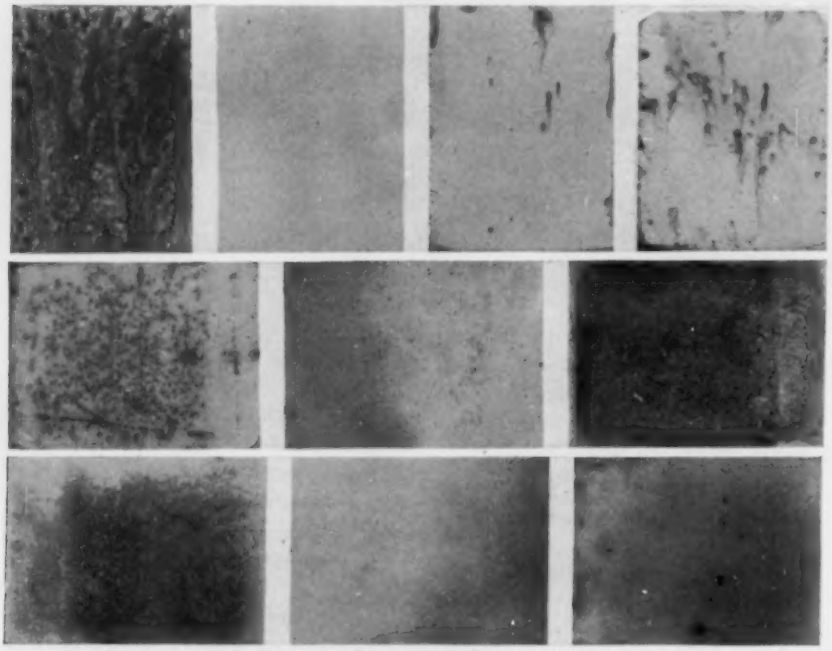
**Engineers are eyeing new plating process that plates chromium directly on steel, equals nickel-chromium corrosion resistance. Method claimed cost-competitive with copper-nickel-chromium plating.**

Engineers wrestling with corrosion headaches are looking closely at a new plating process that deposits chromium free of structural cracks. United Chromium, Inc., New York, developers of the process, claim it allows elimination of copper-nickel or straight nickel undercoat while securing equal corrosion resistance.

Depositing chromium free of cracks directly on steel, United's method, if present test data stands up in commercial practice, makes the advantages of chromium plating available without the expense and complications of present copper-nickel-chromium methods.

Big question for chemical engineers is practicality as a plating method for process equipment. United feels that Crack-free can be plated on any equipment, any size that can fit in a plating tank. Question is—would large-size process equipment plating of chromium be practical? Rate of deposit, one limiting factor, is slower for Crack-free than for nickel (1 mil/hr against 3 to 5 mil/hr). However, United claims that a much thinner coat of Crack-free will do the job. Problem boils down to testing the new method on specific products, deciding on the basis of all variable factors whether or not it is practical for the particular application. United has not yet tested its method on large process pieces, and engineers will have to watch future developments in this line before making a decision as to the method's large-scale usefulness in process application.

At the same time, corrosion resistance is only part of United's claim for the new coating. The Crack-free deposit is said to be softer and more ductile than ordinary chromium (3 to 4 times as ductile) and yet remains a hard, wear-resistant coating. Its adhesion is claimed to be excellent, its non-galling, non-seizing, and levelling properties, are claimed to be much improved.



*Top row:* Salt spray test, chromium directly on steel (thickness—0.0003 inch). L. to r., ordinary chromium, 24 hours exposure; Crack-free, 24 hours; Crack-free, 100 hours; Crack-free, 175 hours.

*Second row:* Five months outdoor exposure, chromium directly on steel (0.0002 inch); l. to r. Crack-free, Crack-free buffed, ordinary chromium.

*Third row:* Five months outdoor, chromium directly on steel (0.0005 inch); l. to r. Crack-free, Crack-free buffed, ordinary chromium.

**More about the development of crack-free chromium** was recently revealed in a research report available through the Office of Technical Services, Dept. of Commerce. Performed at Rensselaer, the work investigated fundamental principles of chromium deposition and evaluated conditions existing in electroplating baths from the standpoint of thermodynamic and reaction rate theory.

Experiments described in the report indicate that poor quality of plate is often due to the effects of hydrogen evolved in the plating process. It was found that improvement might be effected by using addition agents in the chromic acid bath to reduce the efficiency of deposition of hydrogen on the plate. The permeability of the plate to hydrogen may be reduced by alloying the chromium with some other element, such as iron.

Confirmatory studies covered the use of these additives in the chromium bath and the possibility of obtaining crack-free coatings by the use of various alloys. □

### DULL AND DENSE

Depositing in a dull, light gray matte finish, which can be readily buffed to the common high polish chromium finish, a photo-micrograph of a Crack-free cross-section shows a dense, continuous structure without the cracks that show up on a normal chromium plating deposit. The coating, while more ductile than ordinary chromium, is still not as ductile as nickel—a factor which can have considerable bearing on the method's applicability in the chemical process industries. In addition, chromium is difficult to weld, necessitating, for the most part, the plating of already welded pieces.

A major reason for the crack-free structure of United's new plate is the fact that shrinkage of the deposit is slight. Shrinkage of the surface has been a big factor in chromium's cracking.

### SELF-REGULATING

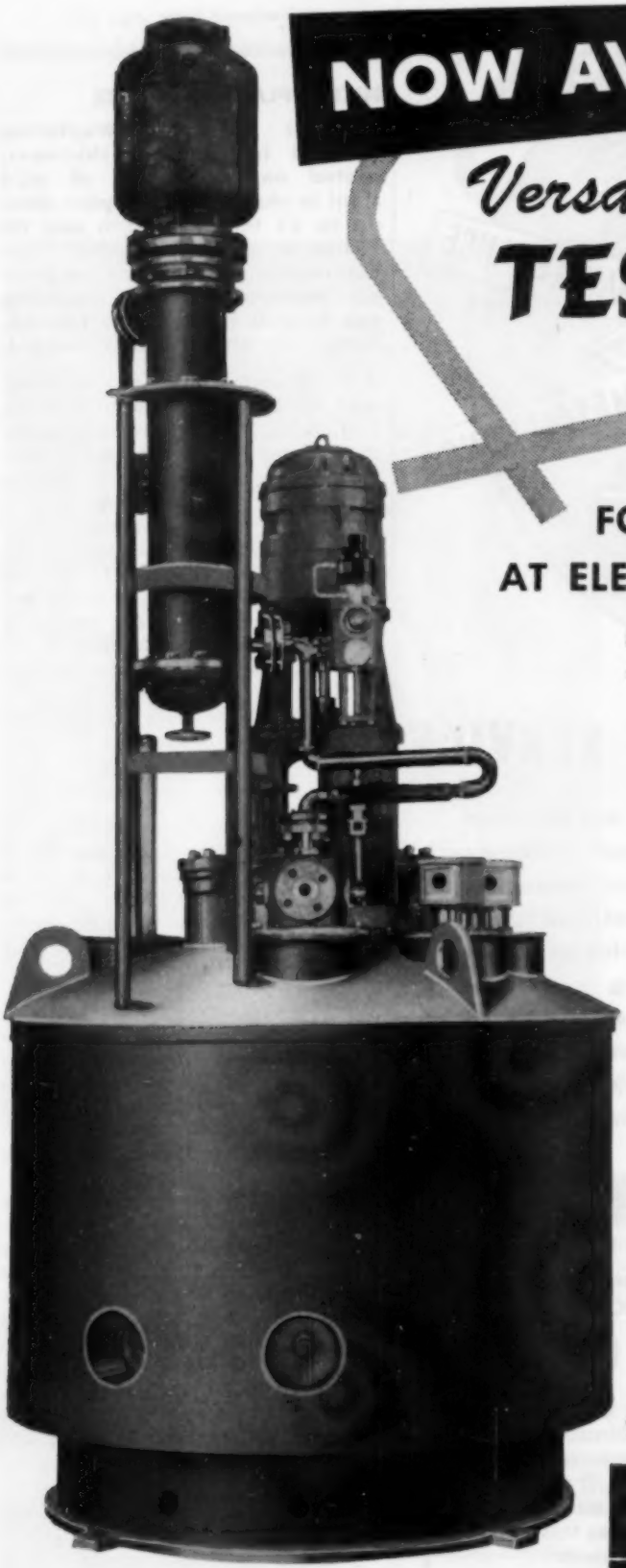
Differences in the Crack-free method lie both in operation of the process and composition of the bath. Equipment is the same as in any chromium electroplating process and general procedure is identical. Bath is self-regulating, including the correct proportion of catalyst determined by solubility of United's special chromic acid compound, Unichrome SRHS Compound CF-500.

United's process has, on the basis of present laboratory and pilot plant data, great potential for industry. If the company's claims and facts stand up in larger and wider commercial applications, corrosion engineers will have found a valuable new tool. Certainly, the process bears watching.

(*Continued on page* 68)

# NOW AVAILABLE

## *Versatile* Beth-Tec TEST-UNIT



### FOR HEATING AND COOLING AT ELEVATED TEMPERATURE LEVELS

Process heat transfer with molten eutectic salt at 650-1,000°F. accomplished with compact pilot unit.

**BETH-TEC TEST UNIT**

The versatility of this heating and cooling unit is shown by:

- Heat input (electrical) up to 150,000 Btu/hr.
- Molten salt for process up to 10 cu. ft.
- Salt circulation 5 g.p.m. at 35 foot head or 50 g.p.m. at 20 foot head.
- Salt working temperature range 650-1,000°F.
- Cooling capacity to 150,000 Btu/hr.
- Equipped with instruments for automatic control.

**Some Uses of BETH-TEC:**

Heating and cooling exothermic reactions.
Ignition of catalyst.
Heating metal-forming dies.

**Write for illustrated descriptive folder.**

*BETHLEHEM OFFERS*

other designs in larger capacities for gas and oil firing.

**BETHLEHEM**

**Foundry & Machine Company**
Process Equipment Division
BETHLEHEM, PENNSYLVANIA

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***CONSECO SERVICE is two-fold.*** **On one hand, our engineers will design, redesign, build, erect, and install practically everything in a modern power or chemical processing plant except the building, electrical equipment, and turbo-generator. On the other hand, we will dispatch an expert crew to your plant for retubing, rebuilding, and maintenance of any type of tubular equipment, or metallizing . . . ANY HOUR, DAY or NIGHT, SUNDAYS and HOLIDAYS. Conseco's coordinated manufacturing and maintenance services meet every need in the Power and Processing fields.**

**CONDENSER SERVICE & ENGINEERING CO., INC.** CONSECO

Designers and Builders of Equipment for Power, Refining, Chemical and Marine Industries

64 Bloomfield Street
HOBOKEN, N. J.

## Equipment Designed and Built by CONSECO

**Conseco and its subsidiaries design, build, and install power and processing equipment and accessories, some of which are listed here. Purchasers of Conseco equipment benefit from our maintenance division's quarter century experience in rebuilding, modernizing, and maintaining our own as well as competitors' equipment. This coordination assures easy accessibility for maintenance and low operating cost. Send for bulletins covering equipment in which you are interested.**

HEAT EXCHANGERS
CONDENSERS
EVAPORATORS
STEAM JET AIR EJECTORS
STEAM GENERATORS
PRESSURE VESSELS
CENTRIFUGES
FILTERS and STRAINERS
PUMPS, INSTRUMENTS, SPECIALTIES

*(Continued from page 66)*

### NICKEL PLATE—KING SIZE

**Low-cost nickel electroplating tailored to required thickness, plated on any grade of mild steel in sheet, plate or pipe sizes up to 21 feet in length and 60 inches in diameter, offers low-cost corrosion protection for process equipment. Plate resulting can be roll formed, die formed, flame cut, sheared and welded.**

A nickel electro-plating process, developed by Bart Mfg. Corp., Belleville, N. J., brings electro-plated nickel equipment of any desired thickness of plate from .006 to 0.020 in., and in sizes up to 60 inches in diameter, into the area of low-cost corrosion resistant equipment for the chemical engineer.

The new material, called Lectro-Clad steel, readily fills a gap in nickel protected corrosion-resistant processing equipment. Since the thickness of the plate is not a function of the thickness of the steel, any thickness of nickel, within the above limits, can be plated on any thickness of steel.

#### Already Extensive

Growing from the needs of atomic energy installations, where nickel-lined seamless steel pipes and fittings were necessary, often in large sizes, the new plate spread rapidly in use to the chemical and petroleum industries, to pulp and paper manufacture.

#### King-Size

Bart has, at present, facilities at Cleveland, Ohio, for fabricating steel pipe from 2 to 54 inches in diameter in 20-21 foot random lengths. Fabricating equipment is in the same plant as the plating facilities.

Plating technique at Bart departs from the conventional methods somewhat by plating the largest part of its pipe in a vertical position. All pipe sizes, from 2 to 60 inches in diameter are plated in tanks 24 feet deep and 8 feet in diameter. Sixteen such tanks are employed in the plating cycle. While Bart has all the equipment required to handle these large pieces, it can also plate small pieces, clads plates as well as pipe, internal as well as external plating is normal procedure.

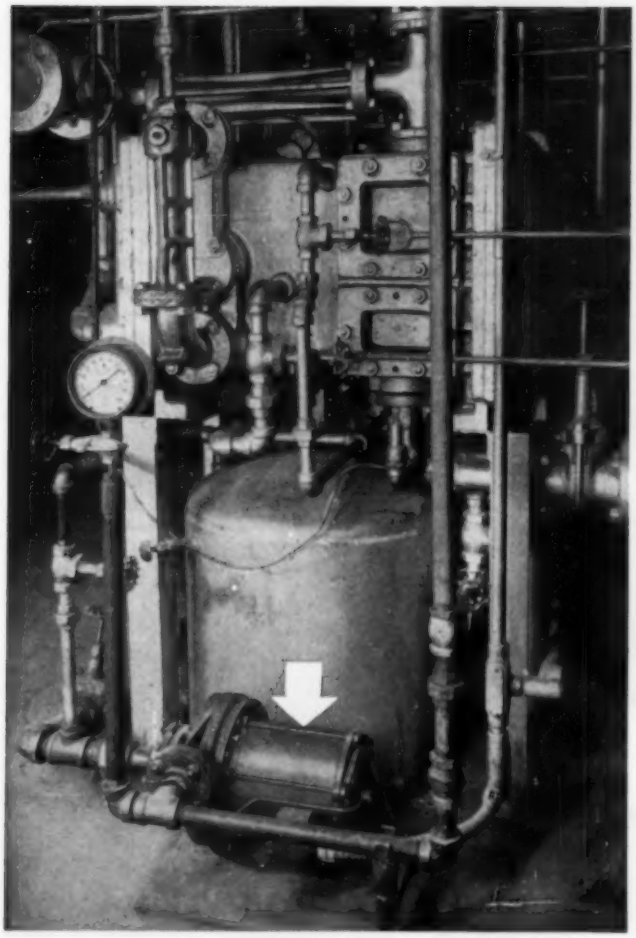
The process provides a smooth, pore-free, ductile, "dull" coat.

Just announced is Colorado Fuel & Iron's (New York) appointment as Bart's exclusive sales agent for the chemical process industries. For further information, encircle No. 100 on Data Service postcard. □

# Chempump

## prevents costly leakage

## *at*
## *Bakelite Company*



2 hp *Chempump* installed on condenser unit at Bound Brook, N. J., plant of Bakelite Company. This is a vacuum system operating at 28 inches of mercury. Pump discharges at 9 psig. Based on outstanding performance of *Chempump* under extreme vacuum, company is purchasing additional units.

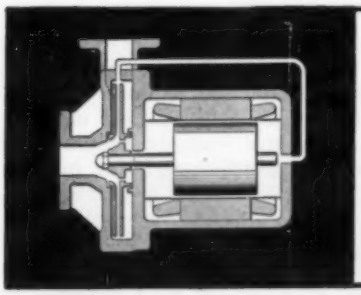
PUMPING condensate from a condenser unit under vacuum posed a critical problem at Bakelite Company. If the pump lost its prime, the condensate would fill up the tank and back up into the system, causing considerable lost time and damage. Any air leakage would destroy the vacuum and render the system inoperative.

Previous pumping equipment required frequent maintenance due to stuffing box leakage. With installation of a seal-less *Chempump,* however, all leakage and vacuum problems were eliminated. Virtually maintenance-free, *Chempump* has shown outstanding performance.

Another tough leakage problem solved by *Chempump.* With this seal-less combined motor-pump unit, normally hard-to-handle fluids can't leak or become contaminated. Periodic inspection to indicate necessity of simple bearing change is the only maintenance required.

Your process can benefit through *Chempump,* too. For details, send for new 16-page Bulletin 1010. Chempump Corp., 1300 E. Mermaid Lane, Phila. 18, Pa.

*Engineering representatives in over 30 principal cities in the United States and Canada.*



*Chempump* combines pump and motor in a single hermetic unit. Pumped fluid enters rotor chamber; no shaft sealing device required.

Approved by Underwriters' Laboratories. Available in wide choice of materials . . . from ⅓ to 7½ hp. Capacities to 250 gpm. Heads to 195 feet.

**Chempump can't leak!**

*Chempump* —first in the field...process proved

**Chempump Corp., 1300 E. Mermaid Lane, Phila. 18, Pa.**

Please send me details on *Chempump* for:

_____
(application)

*Capacity*_____ *Total dynamic head*_____

*Name*_____

*Title*_____

*Company*_____

*Address*_____

*City*_____ *Zone*_____ *State*_____

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Fabrication
is our Business
Whether its a kettle, reboiler, reactor or other process equipment, Manning & Lewis engineers and craftsmen are ready to design and fabricate a unit, tailor-made to fit your particular process need, and priced to fit your budget.
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## INDUSTRIAL NEWS

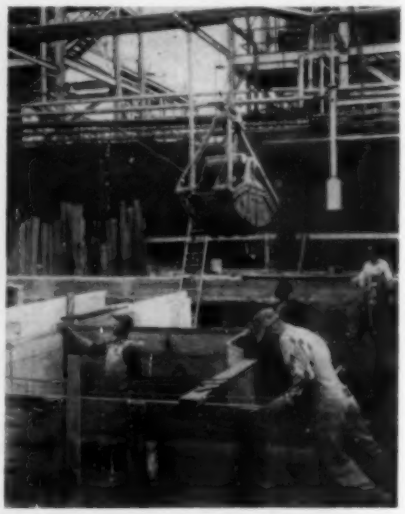
### SYN. RUBBER PLANTS EXPANSION PROGRAM

**$200-$300 million is the possible bill for expansion of rubber producing facilities within the next few years,** according to A. L. Freedlander, president of Copolymer Corp.

To back up Freedlander's statement, rubber companies are erupting in a rash of expansion plans triggered by the taking over of Government facilities by private concerns.

At Copolymer—Take over of the two synthetic plants it has operated for the Government at Baton Rouge, operating on six-day, around-the-clock program, no transfer shut-down, eyeing expansion.

At Firestone—Take over of Lake Charles, La., synthetic plant ($13 million) and Akron cold rubber plant ($2.8 million), immediate expansion plans already underway to cost $1.2 million, boost production at Lake Charles 13%.



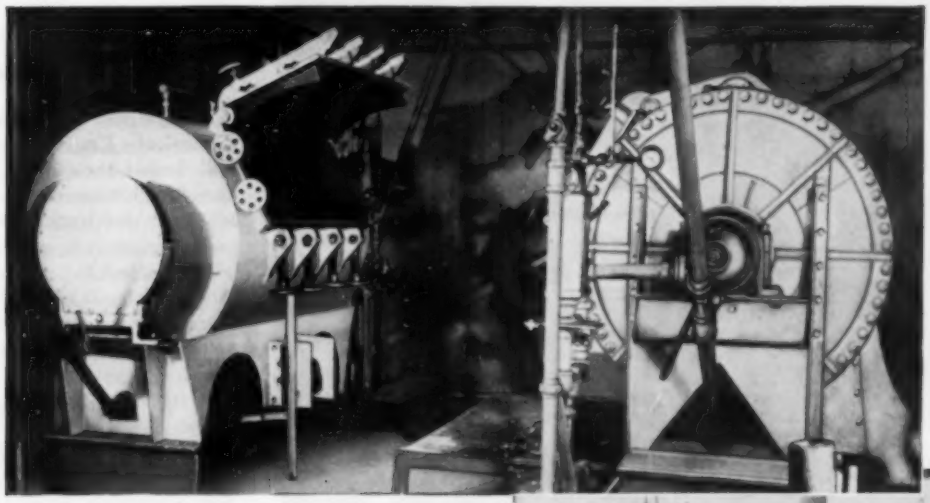
**$1,200,000 expansion already underway at Firestone as workmen prepare foundation for compressor building at recently purchased Akron synthetic latex plant.**

At Goodyear—Take over of latex plant at Akron ($2 million) and synthetic plant in Houston ($12 million).

At American Synthetic Rubber—Expansion of handling facilities, installation of new equipment to produce several polymers in addition to those already produced.

For future, Freedlander estimated rubber consumption as 1.5 million to 1.8 million long tons by 1960, or as much as 40% more than in 1950. □

*(Continued on page 72)*



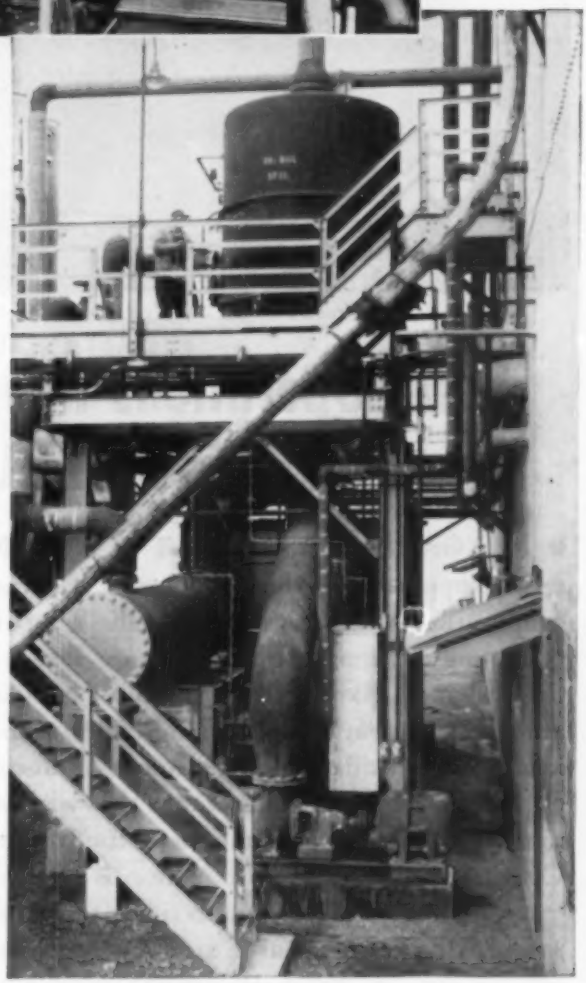
Above: Conkey Rotary Leaf Pressure Filter separating coal resins and solvents.

# PROFIT

## with Processing Equipment

Operators of crystallizers, evaporators and filters know that the right processing equipment can make or break a profit margin. Conkey crystallization, evaporation and filtration equipment have operating profit "built in" . . . an integration of design, engineering and fabrication.

Conkey designed and engineered equipment is fabricated by Chicago Bridge & Iron Company. Four plants, completely equipped to meet the most exacting specifications, are strategically located throughout the country. So when your problems involve crystallizers, evaporators or filters, write our nearest office. There's a Conkey engineer ready to help.



Above: Conkey Horizontal Tube Forced Circulation Evaporator.

**CHICAGO BRIDGE & IRON COMPANY**

Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PA.

**CONKEY** EQUIPMENT

Atlanta • Birmingham • Boston • Chicago • Cleveland • Detroit • Houston
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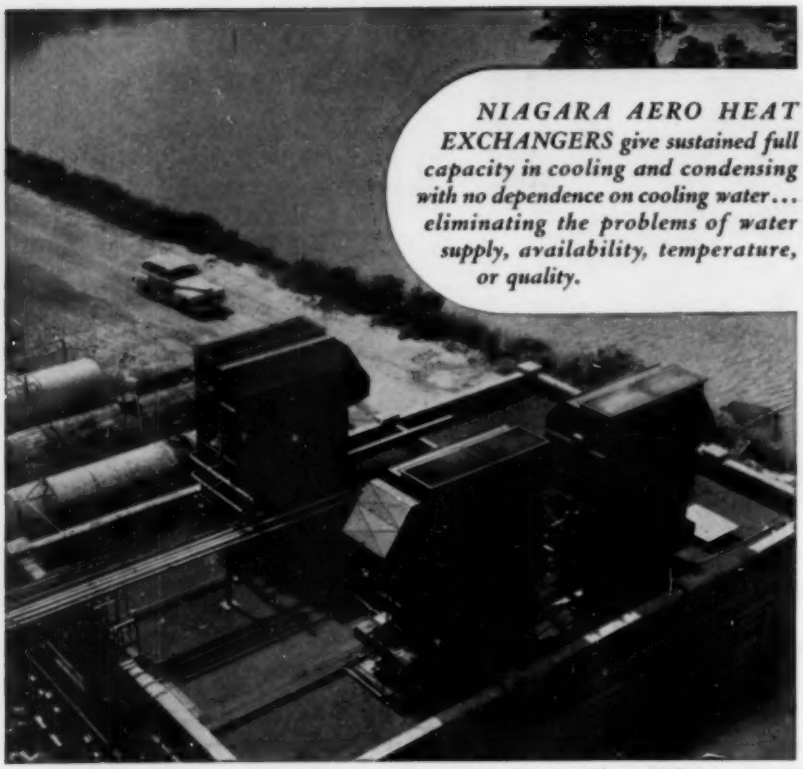
San Francisco • Seattle • Tulsa


*NIAGARA AERO HEAT EXCHANGERS give sustained full capacity in cooling and condensing with no dependence on cooling water... eliminating the problems of water supply, availability, temperature, or quality.*

*Niagara Aero Heat Exchangers at a Plant of the Heyden Chemical Corp.*

# Still Operations Improved by a New Cooling Method

• NIAGARA AERO HEAT EXCHANGERS cool the reflux supply or condense vapors at a vacuum by controlled evaporation of water directly on the heat exchange surfaces.

Liquid or vapor temperatures are always held constant by the Niagara "Balanced Wet Bulb" control method, which automatically varies the cooling effect proportionately to the load. The distillation is therefore uniform throughout all changes in climatic conditions the year around; it is the same in the heat of summer as in the freezing cold of winter. Continuous maximum production is thus insured.

Non-condensibles are effectively separated at the condensate outlet, with notable sub-cooling after separation for greater vacuum pump efficiency.

Use of Niagara Aero Heat Exchangers reduces your operating costs and removes many sources of your troubles in distillation column operation. Ask for new bulletin #120.

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Over 35 Years Service in Industrial Air Engineering

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*Experienced District Engineers in all Principal Cities of U. S. and Canada*


## INDUSTRIAL NEWS

**A $2,500,000 expansion at Goodrich Chemicals Louisville,** Kentucky plant will double the plant's present capacity for the production of Hycar special-purpose American rubber and latex.

Construction is underway with completion scheduled for early next year. The Girdler Company of Louisville, Kentucky, is general contractor.

The Louisville expansion program is closely allied with the company's new $8,500,000 acrylonitrile plant nearing completion at Calvert City, Kentucky. Acrylonitrile raw material for Hycar rubber and latex will come to Louisville for processing from the Calvert City plant. □

**United States Rubber Co. is doubling the size of its foam rubber plant** in Santa Ana, Calif. The addition to the Santa Ana plant will contain 89,920 square feet of floor space, will be joined to the present plant opened in May, 1954. Construction starts this month. □

**High temperature fibers finer than human hair** will be manufactured by the newly established Ceramic Fiber Project unit of Carborundum Company, Niagara Falls, N. Y.

Main job of the new unit will be the development of new production techniques and applications for ceramic fibers (known as Fiberfax).

As blown from molten aluminum oxide and silica, the fiber is a cotton-like mass of extremely fine filaments arranged in random fashion, remains stable at temperatures as high as 2300 degrees F. Commercially available in bulk, paper and block forms, the fiber is used in insulating, soundproofing, and gasketing jet engines; as an insulator and filter in the electrical, papermaking, industrial heating, and chemical industries.

The new unit will also develop new products and conduct physical and market research. □

**New high pore volume cracking catalyst** for the petroleum industry has been developed by American Cyanamid. The new catalyst, designed to help refineries save in cost of operation through increased stability and cracking efficiency, has been intensively tested by Cyanamid in cooperation with over 12 refineries.

Claims for new catalyst: High pore volume, most effective pore diameter, best control of particle size distribution, most efficient degree of hardness, produces highest yield of octane. □

Already proven a commercial success in France, **a new process for the continuous production of fatty alcohols** by high pressure hydrogenation is now available to American industry.

Developed by the French firm, Societe D'Innovations Chimique, S.A. (Sinnova), largest detergent manufacturer in France, the process is being offered in this country by Rust Engineering as exclusive licensing agent for the French firm and its allied company, American Alcolac Corporation.

Recently, Sinnova put on stream an additional high pressure hydrogenation plant embodying the process now available in America. The new plant, at Toulouse, is part of Sinnova's continued expansion of its high quality fatty alcohol production, which it has been operating for over 20 years.

The process consists of the continuous introduction of fatty acids from tallow or vegetable oils into a tower reaction chamber where they contact hydrogen and a nickel-chromium type catalyst. After reaction, the products of reaction are continuously separated, refined by continuous fractional distillation, and the hydrogen and catalyst recovered. Inherent in the plant design is the efficient recovery of heat and material streams.

Sinnova's facilities are open for inspection and are available for test runs on any special materials, through Rust Engineering. □

**General price reduction in lithium and lithium compounds** sold by Lithium Corporation of America, is result of company's new chemical plant at Bessemer City.

New prices (carload lots): Lithium metal, $11.50/lb., down $1.50; lithium carbonate, $0.85/lb., down 5¢; lithium hydroxide, $0.90/lb., down 7½¢.

Reductions in less than carload lot prices have been made on 108 of the company's products. □

*Development Center — Nitrogen Division*
*Allied Chemical & Dye Corporation — Hopewell, Virginia*

**LABORATORY SAMPLE FROM**

# *Wigton-Abbott*

***RESEARCH LABORATORIES — DESIGNED — ENGINEERED and Constructed to answer your needs and the competition of tomorrow***

Research or Control laboratories are intricate feats of design. Everything must be planned, designed and equipped to produce utmost efficiency and successful results.

*Wigton — Abbott Corporation* has had long experience in creating and developing Research Laboratories in all fields of industry. A long list of satisfied clients will certify our proficiency in *Engineering* and *Construction.*

*Wigton — Abbott* welcomes your inquiry and the opportunity to place our experienced organization of specialists at your service.

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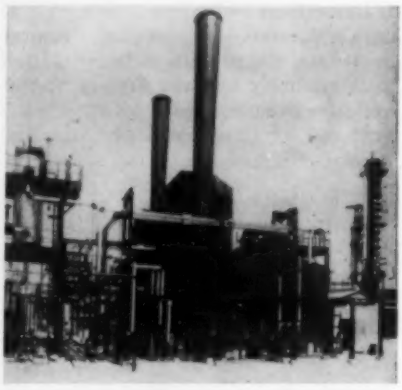
## INDUSTRIAL NEWS

**New multi-million-dollar polyethylene plant of Spencer Chemical** at Orange, Texas, was dedicated recently, 21 months after ground breaking ceremonies.



Designed to produce 45,000,000 pounds of the resin a year, Spencer's plant was put into automatic production in the unusually short time of 15 minutes after initial production.

Ethylene used comes from Gulf Oil's Port Arthur refinery. ☐

Producing styrene monomer for the first time a year ago, Foster Grant, Leominster, Mass., will expand production of its Baton Rouge plant to more than **double its present capacity.**

With the new capacity, Foster Grant enters the outside market with its monomer, first shipment going to Copolymer Rubber and Chemical Company at Baton Rouge on the occasion of that company's acquisition of Government-owned rubber facility.

The expansion program at Baton Rouge will provide a capacity of more than 50 million pounds of styrene annually. The plant was originally constructed to produce 24 million pounds annually, using chemical manufacturing processes first developed in Germany and unique to this country.

Additional expansion will be considered if market conditions warrant any further enlargement. ☐

**Another large plant for the manufacture of aniline oil** at Moundsville, West Virginia, is in the works for National Aniline Division of Allied.

The new aniline plant joins plans to construct a major plant for production of isocyanates at Moundsville, and will be a duplicate of the present plant which commenced operations in January, 1954.

Same catalytic process developed in the company's research laboratories will be used. Raw materials are mixed acid, benzene and hydrogen—all produced by Allied. ☐

## INDUSTRIAL NEWS

**Proposed expansion of nitric acid and Spensol (ammoniating solutions) facilities** at Spencer Chemical's Vicksburg, Miss., plant will foot a bill of $1,500,000.

Market survey prior to beginning construction indicated that the markets of the Southeast could be best served by expanding facilities at Vicksburg rather than locating in any of the other sites considered.

At present the Vicksburg works has sufficient nitric and Spensol capacity to convert 60% of the anhydrous ammonia produced to Spensol solutions. These solutions are used by the manufacturers of mixed fertilizers as a source of nitrogen.

A portion of the ammonia produced at Vicksburg will continue to be marketed as such, but the new expansion will permit the conversion of all the ammonia into Spensol solutions if desired, improving customer service and general flexibility. □

**Engineers will have a chance to evaluate some of the latest electronic instruments in operation** in a new mobile exhibit touring the country for Consolidated Engineering Corp., California.

Designed to help engineers specify electronic equipment on a more tangible basis than studying a catalogue, the mobile unit is much more than a static showing of equipment. In essence it is a demonstration laboratory mounted on a truck-trailer, and every item in the exhibit can be made to work exactly as in an industrial plant.

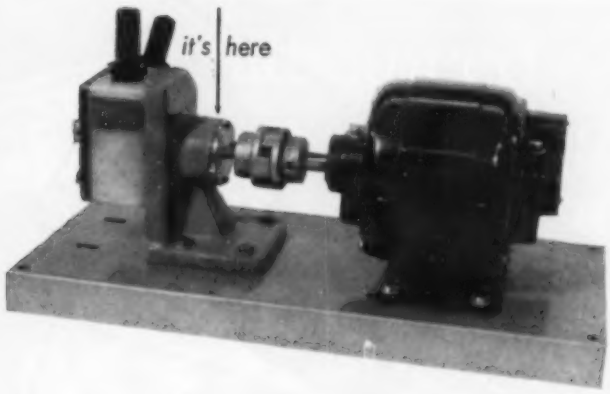
Featuring Consolidated's high-speed data-processing equipment and process-monitoring, analytical and control instruments, the exhibit will travel 25,000 miles giving demonstrations of a new supersensitive leak detector, a mobile mass spectrometer, and a CEC electromanometer, among other industrial instruments.

All instruments are mounted on racks and can be moved to exhibit floors, factories, etc. A conference room and facilities for showing films are included in the unit. □

**A multi-million-dollar titanium tetrachloride plant** being constructed at Natrium, W. Va., by Columbia-Southern, is scheduled to start-up in April, 1956, be in full production 3 months later .

Result of Columbia-Southern's long research on the chlorination of titanium bearing ores, the new plant is another major development by Columbia-Southern in the commercialization of titanium.

Construction is to be done by Catalytic Construction Co., Philadelphia, who designed the plant. □


**VANTON'S** External Bearing

**X-B PUMP**

Without stuffing box, gaskets or valves!

The Vanton corrosion resistant "flex-i-liner" self priming rotary type plastic pump is available in a new design that permanently protects all bearings from fumes or chemical attack.

**Low maintenance** is assured since shaft bearings are external and the rotor assembly is stainless steel. Only wearing part is the quickly replaceable low cost flexible liner.

**Capacities range** from fractional to 5 gpm with 0-50 psi discharge pressures . . . Vanton XB will develop vacuum up to 26" Hg. and will handle corrosive liquids, gases, viscous fluids or abrasive slurries.

**The unique design** of the XB isolates the fluid from all actuating mechanisms or rotating parts. Pumping is accomplished by a rotor mounted on an eccentric shaft, creating a squeegee action on the fluid. Displacement is positive and non-agitating.

**Wide selection** of body block and liner materials makes Vanton XB suitable for an endless list of chemicals, pharmaceuticals and food products. Body blocks are available in: Bakelite, polyethylene, Lucite, Buna N, PVC, and stainless steel. Flexible liners are available in natural rubber, pure gum rubber, neoprene, Buna N, hycar, hypalon and silicone.

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PUMP & EQUIPMENT CORP.
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Quikupl
Stops costly equipment waste! Quikupl fittings can be used over and over with only occasional change of sealing ring. Inventories are cut to the bone.
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QUIKUPL stainless steel elbows, tees, couplings, reducers and adapters add up to substantial savings in time, labor and materials. Installation and maintenance costs are drastically reduced. Light wall tubing can be used instead of pipe, and where tubing is already being used the costs and hazards involved in welding, soldering and flaring can be avoided. Since the only installation tool needed is an Allen wrench, Quikupl simplifies piping layout by permitting close-to-wall and compact installation.

*Technical data and case history information available on request.*

**COOPER ALLOY**
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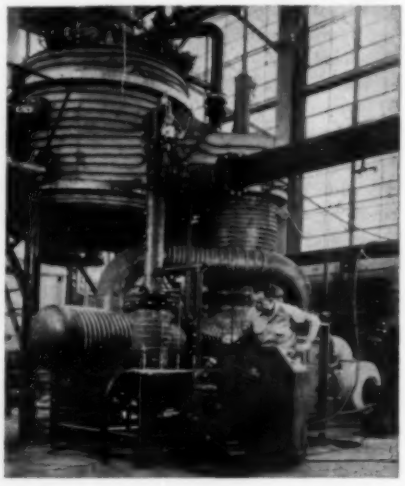
*Valve & Fitting Division*


## PROCESS EQUIPMENT APPLICATIONS

**Now it is possible to fasten lead lining to heavy steel** 15 times faster than by the drill and bolt method normally employed, by using a heavy-duty powder actuated tool of new design capable of driving a stud through 1 inch of structural steel.

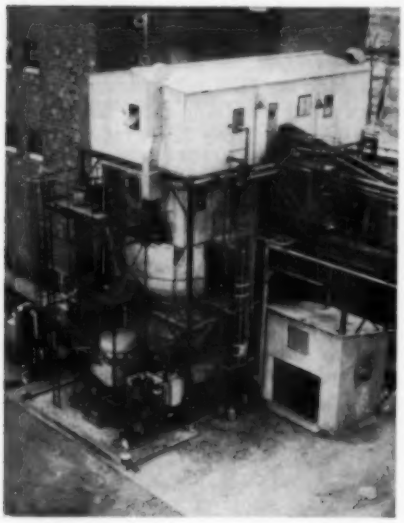
On a recent job, Allied Lead Construction Co., Chicago, used the Ramset tool to drive studs through ½ inch half-oval steel straps, ½ inch of overlapped lead lining, and ⅜ inch steel tank underneath the lead. Each strap was 20 feet long, 27 were needed to fasten the lead, and each strap was fastened in 15 minutes.

Major problem in using a powder-actuated tool for fastening lead linings has been the protuberance of the studs after driving. Since the steel straps must be lead-covered, any protuberance allows the pressure of the liquid in the tank to wear away the lead and leave the straps open for corrosion. This was overcome by using double driver heads on the studs so that the leading sliver head, of low carbon steel, mushroomed and was easily knocked-off by a ball-peen hammer leaving a flush surface for the subsequent lead covering. □



**Controlling extraction of volatile, explosive solvent from Aureomycin feed cake,** is latest application of Mine Safety Appliance's combustible gas analyzer.

The residual cake from Aureomycin manufacture contains traces of the antibiotic and is valuble for animal and poultry feeds. Problem was volatile chemical solvent still in the cake—an aliphatic alcohol picked up during extraction of the Aureomycin.



By processing cake in a three-story Wyssmont drier, the solvent is removed and reclaimed for further use. But a constant check is necessary to prevent explosions. Here the M.S.A. combustible gas alarm system came into play. When the solvent concentration causes the atmosphere in the drier to reach 27% of the lower explosive limit, visible and audible alarms are set off. This serves both as a safety device and as a check on process efficiency.

M.S.A.'s analyzer consists of a detector cell containing one of two heated platinum wires which form a balanced electrical circuit. The second wire is housed in a compensator cell containing uncontaminated air. Any combustible solvent in the air is burned on the heated wire. This unbalances the electrical circuit in direct proportion to the percentage of solvent in the sample. □

◄ **Largest three-stage oil ejector pump ever built** will remove 12½ pounds of air per hour from semi-continuous, vacuum melting and casting furnaces. Latest development in high vacuum pumps, the new unit, built by Consolidated Vacuum Corporation, will handle the gas load of a 1000-pound high vacuum melting and casting furnace all by itself. □

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advanced engineering is the important factor in

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the 4-position all-plastic single control

CYCLOFLOW VALVE

for controlling ion exchange cycles

Completely impervious to acids and alkalies, it assures against corrosion. Leakproof operation is insured by vented and drained isolation chamber, preventing contamination of effluent. Requiring a minimum of torque for operation, the CYCLOFLOW VALVE is adaptable for automatic, semi-automatic or manual operation with no alteration or additional field adjustment of components. Positive valve action obtained by simple fingertip control. Design eliminates spring loading and large unbalanced areas and flat surfaces which cause leakage. Write for copy of Bulletin 600.

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. . . of Duraloy HH Alloy, one of the most widely used high chrome, medium nickel alloys.

Two items concerning these furnace rolls may be of particular interest:

a—the size: 20 feet long—14" OD, ¾" wall thickness

b—welding operations by which reducing cones and shafts (both statically cast of the same alloy) were welded to the centrifugally cast rolls

These two items will serve to emphasize two phases of our service: (1) the large size centrifugally cast tubes we are able to produce and (2) our machining and finishing facilities, including welding.

Our new 16-page general Bulletin — 3354-G — gives complete details. Would you like a copy? When writing or calling would you mind telling us the general nature of your high alloy casting requirements? Better yet, if you have specific requirements on which we could help, let us have the details.

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## INDUSTRIAL NEWS

**Still "trending" upward in use, downward in price, are isocyanates** (see "Trends," CEP, April, 1955). Latest news from field shows drop in price of as much as 50 cents/pound on the new chemicals used to make polyurethane foams.

Company doing the reducing is new Mobay Chemical (joint U.S. venture of Monsanto and Farbenfabriken Bayer, Germany). Mondur TD, a mixed isomer tolylene diisocyanate used in flexible and other type foams, has dropped from $1.40/lb. to $1.20/lb. in 55-gal. lots. Mondur TDS, a 2,4 isomer tolylene diisocyanate used for rigid foams, has been reduced from $2/lb. to $1.50/lb. in 55-gal. lots.

Price reduction indicates closer on-stream probabilities for Mobay's New Martinsville, W. Va., plant, now scheduled for October. Much equipment from Germany has already been delivered. □

Titanium tetrachloride feed material for **Electro Metallurgical Company's new Ashtabula, Ohio, titanium sponge plant** will be purchased from Columbia-Southern's new Natrium, W. Va., plant. Electromet, a division of Union Carbide, is building its plant now, and Columbia-Southern's plant is also in the construction stage.

Under terms of a five-year contract between Electromet and Columbia-Southern, Electromet will supply the ore for production of the titanium tetrachloride as well as buy the finished product.

Electromet's plant, which will have a capacity of 7,500 tons of titanium metal/year, is expected to start up in mid-1956. □

Expecting to double its share of the 400 million pound/year vinyl resin market, **Monsanto is beginning construction of a major expansion in its vinyl chloride** polymer and copolymer facilities.

Being constructed at the company's Springfield, Mass., plant, the new capacity is expected to come on stream early in 1956.

The expansion reflects the probable healthy growth of the market for vinyl resins, in both old and rapidly developing applications. The news also indicates Monsanto's diversification in this field. □

Fluor Corporation, Los Angeles, has been awarded a contract by the Texas Natural Gasoline Corporation for the **design, engineering and construction of gasoline plant facilities** in Coke County, Texas.

Construction is now under way and completion is scheduled late this year. □

**New Custom Products Department** created by Anold O. Beckman, Inc., California, is answer to growing demand for instruments and auxiliary equipment for specialized applications.

Major purposes of the new department: Modify standard Beckman instruments and equipment to meet the needs of specialized applications; Engineer and construct instruments to order which use magnetic susceptibility, thermal conductivity, differential electrical conductivity, or other principles of operation on which the company has completed basic research or development. □

**Establishment of a new Chemical Division** is a major step in Houdry Process Corp.'s expansion program. The new division will manufacture and sell catalysts used in petroleum and chemical catalytic processes.

Jack C. Dart of Moylan, Pa., manager of research and development and a member of the corporation's board of directors, will be manager of the Chemical Division. □

**Merger of Borg-Warner and Byron Jackson Company,** manufacturer of centrifugal pumps and nuclear power components among other lines of industrial equipment, diversifies $380 million-sales Borg-Warner, affords $32 million-sales Byron Jackson the financial and technical assistance it needs for development.

Byron Jackson will continue to operate as an independent unit.

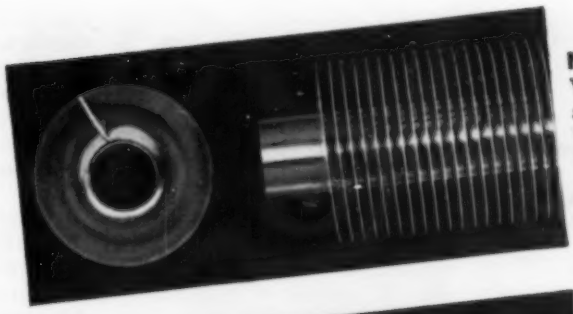
Merger was made on 4-shares Borg-Warner, 5-shares Byron Jackson, basis. □

**Expansion of industrial applications for fibers** is the goal of Celanese Corp. First result: New pilot plant being erected at Burlington, N. C., to put company in better position to service customers who want help with new outlets for fibers.

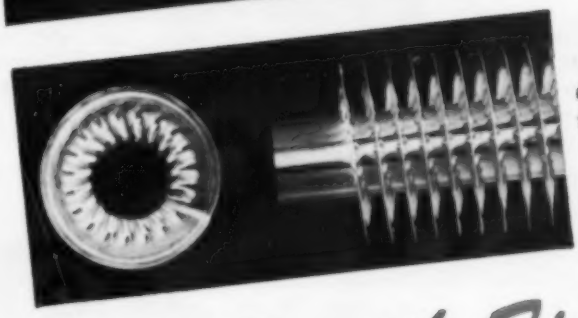
Some areas being studied: non-woven fabrics, low pressure laminates, air and liquid filters, acoustical and heat insulation, and special batting products.

Work is to be concentrated, at least at first, on new applications for the staple fibers produced by Celanese. □

**Consolidation of all Darco activated carbon operations** into Atlas Powder Company's chemicals division transfers sales activities of this major producer of activated carbon to the chemicals division's sales department in Wilmington. H. J. Fornwalt will be group manager. □

**New Smooth Fins**
Wide base provides ample contact surface so that fins can be closely spaced without increasing resistance.



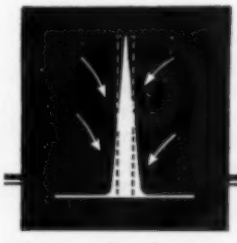
**Old Type Fins**
Crimped to provide necessary contact surface, widely spaced to reduce air friction.

**NEW *Smooth-Fin***
**Aerofin Coils**
**for Greater Capacity**
**Lower Resistance**

Aerofin extended-surface heating and cooling coils now offer you an even greater area of effective surface —even greater capacity—per square foot of face area. Airway resistance is lowered; higher air velocities can be used. The result is extremely high heating or cooling capacity in a given space.

Compact, sturdy, standardized encased units arranged for simple, quick, economical installation.

**Write for Bulletin S-55**



AEROFIN CORPORATION
*101 Greenway Ave., Syracuse 3, N. Y.*

The new Aerofin smooth fins are tapered, with wide base that conducts sufficient heat between fin and tube to make the entire fin effective transfer surface.

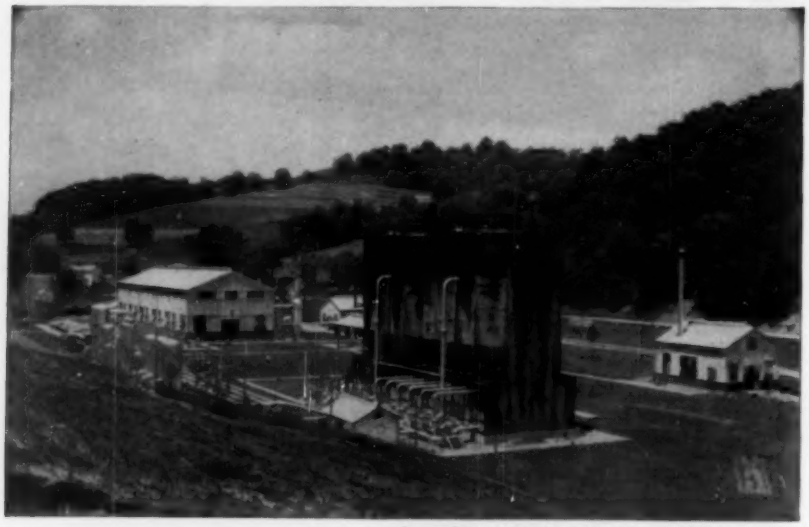
*Aerofin is sold only by manufacturers of fan system apparatus. List on request.*

## GROWING TO MANAGEMENT

**Charleston, W. Va., Section of A.I.Ch.E. conducts poll on how chemical engineers view themselves, their company, and A.I.Ch.E. in relation to advancing into management.**

High interest shown in professional development, seen in recent A.I.Ch.E. New York symposium on subject of "Growth Into Management," led the Charleston, W. Va., Section to conduct a questionnaire quiz of its members. Spadework on the poll was done by members of the section's public relations committee: G. A. Trigaux, chmn.; Wade Fleetwood, Jr.; K. R. Jatko; and R. E. Pyle, all with Carbide & Carbon Chemicals.

The questionnaire received high response percentage (67%). Answers, divided into three groups by length of service of respondees (0-5 years out of school, 5-15 years, and over 15 years), fall into specific groupings, show clearly how engineers feel as professionals these days.

Preston Station, near Waynesburg, Pa., one of the compressor plants of the New York State Natural Gas Corporation.

THE PICTURESQUE AND EFFICIENT PRESTON COMPRESSOR STATION OF

**New York State Natural Gas *Uses* FLORITE**

A showplace for sightly layout and natural beauty of surroundings, the Preston compressor plant of New York State Natural Gas Corporation is also a model of advanced methods and efficiency. It is one of several stations operating at very high pressures in the great hookup that delivers Texas gas to cities in the Rochester-Syracuse region of western New York, and has an uncommon record of freedom from accidents or delays. Gas is dehydrated by two contact towers employed alternately in a 24-hour cycle, one being regenerated while the other is in use. The drying agent is Florite, and the volume of gas processed daily is 160 million cubic feet.

Florite will selectively adsorb 4 to 20% its weight of water—is regenerated by heating to 350° F. Write for literature.

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#### Formal Training

Almost to a man the 258 engineers answering the questionnaire felt that both the engineer and the company benefit from a planned orientation program for the budding engineer. On the other hand slightly more than 25% consider a formal management training program of no value. But while more than 25% turned thumbs down on formal executive training, nearly half the engineers thought they were not being adequately trained in any way for their immediate supervisor's job, although 88% felt they were training themselves for this step up. Post-graduate work was approved by a majority of the engineers.

#### Responsibility

In general, engineers feel they are capable of much more responsibility than they are given at present. An average of 59% of the engineers answering thought they did not have all the responsibility they can take. Here, the length-of-service groupings show the first significant differences. Of the younger men only 48% felt they did not have enough responsibility, while the 5-15 year group had 56% eager to take on more, and the oldest group a full 70% ready for more.

On the other hand only a very low 18% felt that their companies discouraged the young engineer taking responsibility. This seeming contradiction would apparently add up to a lack of positive encouragement from most companies rather than an active opposition.

Perhaps more vital is the figure that shows 35% of the engineers convinced that their authority is not commensurate with their responsibility.

More than 90% thought their ideas were justly considered, 59% believed they were not adequately selling their ideas. Perhaps management could benefit by finding ways to get the ideas of the other 41%.

#### First Job and Lateral Transfer

A low opinion of the first job held as a chemical engineer was indicated by a high percentage of the answers. Only 52% were favorably impressed by the first job, 50% felt it did not measure up to what they had been told in school, and 35% felt it fell down even in view of what industry had led them to expect. Some 28% felt the first job actually hindered their progress. In the latter case, a far greater percentage of the older men, 36%, considered their first job an actual hindrance.

In the matter of frequent moving around in jobs on the same level, some 85% thought this would be a benefit to both them and their companies. A

(*Continued on page* 81)

## GROWING TO MANAGEMENT

(*Continued from page* 80)

high percentage, 93%, believed that their respective companies should help locate the best spot for them within the company, the spot where they would be happiest.

#### Salary

Fairly large dissatisfaction with salary levels was shown by the engineers. Some 5% felt they were perhaps a bit overpaid, 68% felt they were adequately paid, but only 59% felt that engineers in general are paid enough for the work they do.

Bonus instead of raise got a rousing thumbs-down, with only 22% favoring such an idea.

In the matter of adequate pay for engineers in general, it was the middle group, 5-15 years on the job, that felt most strongly that pay was inadequate.

#### Communications

Most of the engineers felt they were growing in their job but only 48% believed they know what management thinks about them. Here a sharp division by service group showed up. Only 33% of the youngest men felt they knew what management thought of them, 44% of the middle group, and 63% of the older men.

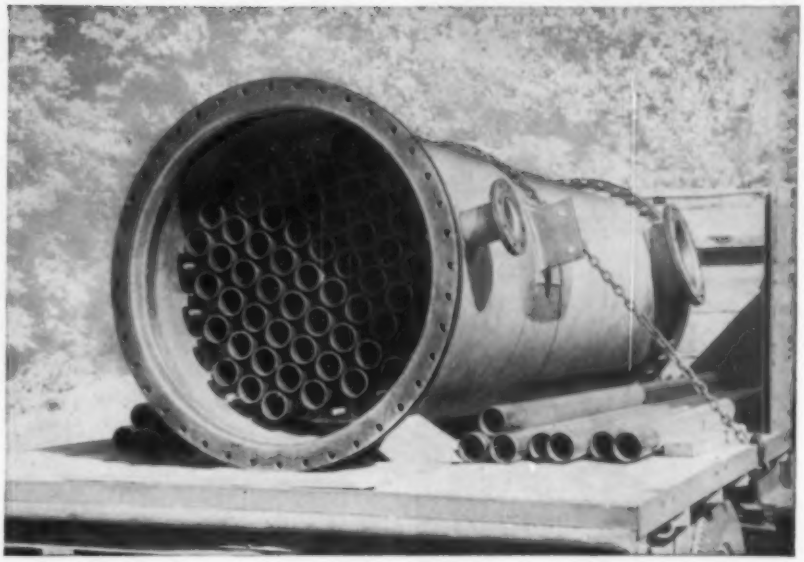
#### The Society's Role

Nearly all of the younger engineers (94%), favored A.I.Ch.E. study courses, with the experienced men favoring them even more (97%). Large percentages thought that regional and national meeting attendance was both encouraged by and beneficial to the companies.

Attendance at A.I.Ch.E. meetings was considered an important help in growth to management by 87% of the engineers, with nearly 100% of the younger men convinced of this fact.

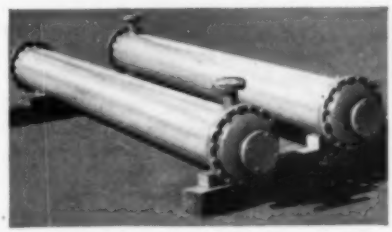
A strong "No" (96%) was the answer to the idea of a pay scale set by A.I.Ch.E. An A.I.Ch.E. sponsored examination as a requisite to becoming a recognized chemical engineer was also rejected by 63%.

**Interesting odd-fact:** only 45% of the chemical engineers thought there was a real engineer shortage! And the distribution of opinion by experience was great: 64% of the long-service men thought there was a shortage, 37% of the middle-experience group thought so, and only 33% of the youngest men said yes. Is it the broader view of the older men, or the hot breath of competition on the younger men?

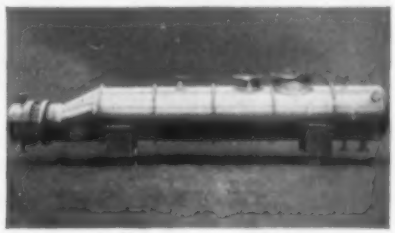



**Special heat exchanger materials are well known at Downingtown!**

**Enamel-Lined Tubes.** This stainless steel heat exchanger, with enamel-lined tubes, solved a serious set of problems which included high temperatures . . . heavy corrosion . . . intermittent operation . . . and a tight budget. It now operates at 150% of design capacity, at a temperature of 1200° F.—and the owner reports trouble-free service from his Downingtown unit. Dimensions: 28″ diameter x 10′ 0″ long. Stainless steel shell. Tubes: 3½″ O.D., lined with high temperature enamel.



**Ampco 8**—Downingtown engineered these two fixed tube sheet benzene condensers for export. Process conditions required copper alloy tube sheets, yet the customer did not want a gasketed joint between tube sheets and shell flanges. So we welded the Ampco 8 tube sheets directly to the steel shells, thus saving the cost of alloy shells. Dimensions: 14″ diameter x 12′0″ long. Eighty copper tubes, 1″ O.D. x 14 gauge. Ampco 8 tube sheets ⅞″ thick. Ampco 8 heads ⅝″ thick. Design pressure is 75 psi on shell and tube sides.



**Solid Nickel**—This solid nickel reboiler for vacuum service—one of eight identical units fabricated for one customer—was engineered by Downingtown to use a minimum amount of scarce and expensive materials. The double tube sheet construction required special assembly techniques. Notice the large nozzles, which were installed with a minimum of distortion by using proper care and skill during welding. Made of ¼″ solid nickel. Dimensions: 34″ diameter x 17′ 0″ long. Has 292 nickel U-tubes, 1″ O.D. x 16 B.W.G.

We furnish complete thermal and mechanical designs, or fabricate to your plans. Send now for additional information.

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Who starts-up your large items of processing machinery in the new plant or process unit? It should be done under the supervision of a qualified representative from the equipment manufacturer's staff, believed a majority of members of the **Chemical Equipment Manufacturers Association** at their May meeting at the Chemists' Club in New York City.

While specific cases vary with the nature of the equipment, it was felt that if alignment, clearance setting of rotating parts, electrical values, or other such variables are critical and the investment in the machinery is enough to be in the "capital item" class, then manufacturer-supervised start-up will protect both user and seller.

Some manufacturers of processing equipment reported they already incorporate the cost of such early inspection and start-up supervision in their selling price, so stating this in their sales contract. Others offer it (as a matter of policy) on the basis of a fee depending on time and distance. The latter was reported to have the disadvantage of not every controller agreeing on what constitutes reasonable expenses for travel. □

**Antibiotics from the North Pole?** Possible, at least that is what antibiotic producer Pfizer seems to think, is helping back American Polar Basin Expedition.

The expedition, headed by Lt. Col. J. F. Stanwell-Fletcher, top Arctic naturalist, expects to be back in this country sometime in the middle of June, will bring much information including soil samples dredged from the bottom of the sea under the Pole. It is in these samples Pfizer hopes to find possible new antibiotic treasures.

Nothing new for Pfizer, which tested 100,000 samples before finding Terramycin, the soil is a little far afield, may prove valueless. In fact there is no guarantee there will be any life in the soil at all. But if there is, there will be microbes, and where there are microbes there can be antibiotics. Anyway, Pfizer feels, it's worth a try. □

**Product obsolescence is both boon and bane** to the giant pharmaceutical industry, A. J. Greene, Pfizer, admitted recently.

Boon: Threat of continual outmoding of product stimulates intense research activity, continual development of new and better products.

Bane: When does the company go ahead with commercial production sure the plant will not be outmoded by new discoveries within a few months? □


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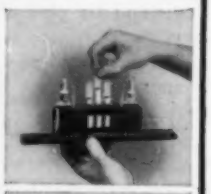

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**Student Problem Contest entries** are all in, committee of judges already at work deciding who will win the prizes.

Results of the rigorous contest will be known at the Awards Banquet during the Annual Meeting in December when the coveted prizes will be awarded to the students who best solved this year's problem—a full-scale, practical problem in the evaluation of a commercial solvent recovery process for a protein manufacturer.

The contest, held each year, is one of the highlights of student chapter activities. □

**Student Awards in chemical engineering** by the Central Ohio Section were the highlight of the Annual Conference for Engineers held at Ohio State May 6.

Annual chapter scholarship award to A. E. Jones of the University, and A.I.Ch.E. National Student Contest Awards to D. S. Nantz and C. W. Thomas.

Professional award of the American Institute of Chemists also went to an engineering student, F. K. Lane.

A talk on the "Comparative Economics of Selected Process Industries," by Frank Maslyk, Stone & Webster, completed the formal program. □

**Richard Kameros, J. A. Lawrie and Edward Gray** won first, second and honorable mention prizes respectively at the Metropolitan Student Regional Conference on April 30 at The Cooper Union, New York.

The prizes—$10.00, $5.00 and honorable mention, plus year's subscriptions to *CEP* and certificates—went to the best student papers presented at the conference, were offered by national A.I.Ch.E.

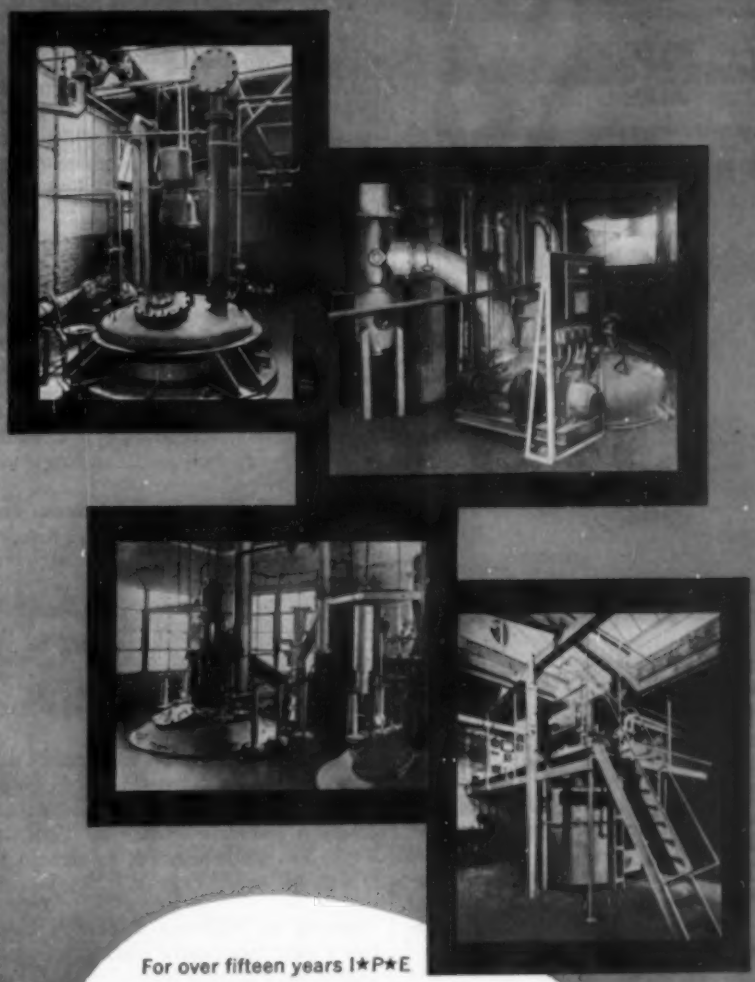
Luncheon and a symposium on instrumentation and automatic control completed the program. □

**A call for plastic pipe standardization** is the latest move in industry's self-regulation. Representatives of manufacturers and consumers of plastic pipe, together with leaders of the technical societies, urged this project on the American Standards Association.

Now a committee will be set up composed of representatives of all national organizations having interest in the savings which the program will effect.

The project will establish a new Sectional Committee in the American Standards Association to deal with tolerances, product markings and shop tests for plastic pipe. □


HOW MANY ALKYD PLANTS MAKE AN EXPERT?



For over fifteen years I★P★E has been providing complete alkyd resin installations to the world's leading chemical manufacturers. From Boston to San Francisco, from Capetown (Africa!) to Kalamazoo, I★P★E units are designed for Dowtherm, electricity, gas or oil heat, and are constructed in all types of stainless steel.

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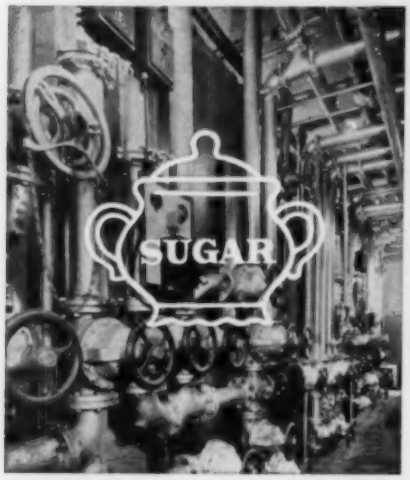


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## A.I.Ch.E.—TO PITTSBURGH?

### —Council Favors Pittsburgh Engineering Center

At its most recent meeting (Houston, May 1) the Council of A.I.Ch.E. passed a resolution declaring its favorable disposition towards locating the proposed Engineering Center at the Schenley Park site in Pittsburgh. In the same action it accepted a recommendation that the Committee of Five Presidents be dissolved.

C. G. Kirkbride, past-president, was appointed as representative of Council to act with appropriate representatives of the other four engineering societies in encouraging the Allegheny Conference on Community Development of Pittsburgh to proceed with the development of a definitive plan for dealing with all of the financial aspects of establishing the five societies in an Engineering Center.

In anticipation of negotiations with the Allegheny Conference, R. P. Kite, as chairman of the A.I.Ch.E. Housing Committee, was requested to work with the Executive Secretary of the Institute to develop information on costs to the Institute and report on any intangible factors resulting from a move from the existing quarters to the proposed Pittsburgh site.

The resolution carries a statement that in taking these actions Council is "indicating its definite interest in the proposed engineering center in Schenley Park, but is not prepared to commit itself at this time."

**Opening of Midwest Research Institute's new laboratory** marked the tenth anniversary of this leading independent research center.

The new building, in Kansas City, is the last word in modern research facilities, cost $1,250,000, has 80,000 sq. ft. floor space, houses research staff of 180 trained scientists, total staff of 250.

Engaging in applied and basic research for industry, agriculture, and the general public, Midwest has worked for some 600 companies in its ten-year history, grosses $2 million per year. □

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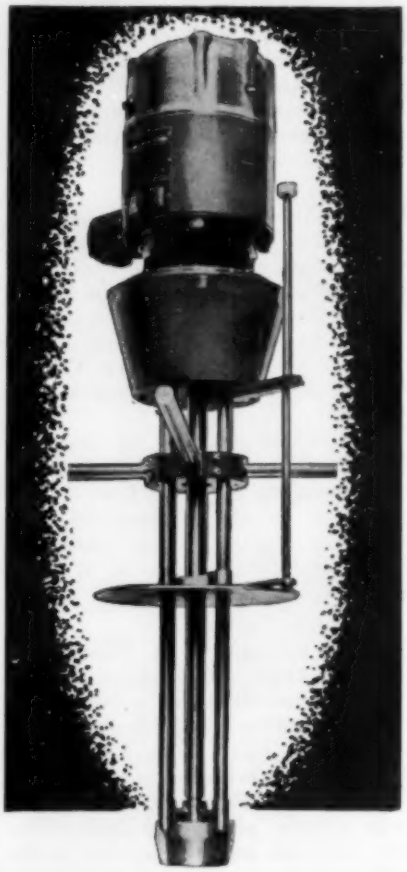

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**Over 1000 willing to present papers** is graphic proof of the interest of U. S. scientists and engineers in the upcoming United Nations International Conference on Peacetime Uses of Atomic Energy at Geneva next August.

That many summaries of papers have been submitted to the Atomic Energy Commission for consideration in response to AEC's call.

Heartened AEC officials point out the two-fold importance of the overwhelming response. It demonstrates this country's desire to share with the world the results of our researches and applications of atomic energy for peaceful purposes. It also shows the substantial contribution we have to offer in this vital field.

To date, 189 papers have been tentatively accepted. Of these, 60 came from colleges and universities, 47 from AEC laboratories operated by both academic and industrial contractors, 46 from other Government agencies—including 34 in the raw material field from the U. S. Geological Survey—, and the remainder from research institutions and industry. □

Anticipating growing peace-time use of atomic energy, Carborundum Metals Company, Niagara Falls, N. Y., has **reduced the price of zirconium metal** for nuclear reactors, and for the chemical industry in general. Drop is up to 40%.

Increasing demand over the past two years led to the price cuts, and to the preparation by Carborundum Metals of an "evaluation kit" containing 17 samples of three grades of zirconium metal for study purposes. Kits cost $150 to any interested company.

New prices: Commercial grade ingots 500 lbs. and over, $14.40/lb. (old price, $22.00/lb.); reactor grade sponge, $14.00/lb. (old price, $22.00/lb); low hafnium ingot, $23.07/lb. (old price, $33.00/lb.). □

**Growing industrial interest in high energy particles** and other radiations from machine accelerators and radioactive sources, has impelled MIT to offer a special one-week summer session on the physical and engineering aspects of high-energy radiations and the techniques of applying them to industrial purposes.

The session on "Ionizing Radiations For Industrial Processing," will be offered at MIT from June 20 through June 24.

Full details of the session can be secured from MIT's summer session office. □


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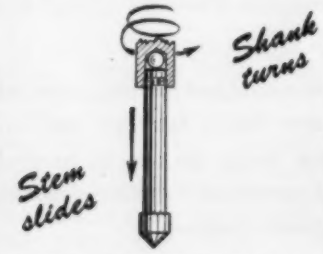


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## FIRST ATOMIC EXPOSITION

**Another giant step will be taken in Cleveland, December 10 through 16, when the world's first major atomic exposition will open under the guidance of A.I.Ch.E.**

**To be held in conjunction with the Nuclear Congress, the Exposition marks a definite milestone on the road to industrial development of atomic energy.**

When the Nuclear Congress gathers in Cleveland's giant Public Auditorium next December, representatives of 22 business and technical organizations numbering their combined memberships at the 400,000 plus mark will be able to see all the latest developments in peacetime atomic energy for industry at A.I.Ch.E.'s Atomic Exposition.

Occupying five exhibit halls in the Public Auditorium, the Exposition, like the Congress, will deal with almost every phase of nuclear developments.

The first mailing of the floor plans has already gone out to the more than 300 companies who want to exhibit at the Exposition, and Cleveland is braced to accommodate the influx of atomic-minded engineers and scientists expected in December.

Full details of floor-space and other matters can be obtained from Exposition headquarters in Detroit. □

**A study of reactor technology by Combustion Engineering, Inc.,** under the Industrial Participation Program of the Atomic Energy Commission, has been approved by AEC.

Combustion Engineering will study design and evaluation of large reactors for central station power production and of small size reactors for special applications, design of reactor fuel elements, and development of fuel element fabrication processes.

The Atomic Energy Commission will make available the reactor technology already developed and will provide consultation services of its personnel and of contractor personnel as required. □

## News of the Field
FROM LOCAL SECTIONS

**East Tennessee.** Paint research is far ahead of the actual conditions being met in the use of paint, said J. S. Long, Devoe and Raynolds, speaking to the April 14 meeting of the East Tennessee Section.

Expanding on the subject, "Modern Developments in Paints and Resins," Long pointed out that many industries are not utilizing the known factors to obtain good results in their painting programs.

Particular emphasis was placed on the problems of painting metals, a subject of concern to all chemical engineers. Six conditions must be met to obtain lasting results when painting metals: the metal must be clean, a first quality rust inhibitive primer must be used, two coats of primer should be put on, the finished coats should be at least four mills thick, the painted vehicle must have good adhesive properties, and the paint must have the chemical resistance necessary to withstand the atmosphere in which it is used.

—P. C. Underwood

**Southern California.** New chairman of the Southern California Section is Chairman-Elect R. E. Vivian. His predecessor, S. G. Sevougian, Dow, has relinquished his office due to transfer to Dow's Framingham, Mass., plant.

Sevougian will henceforth be active in the Boston Section.

—F. E. Rowe

**Denver, Colo.** The new $30 million seamless tube mill of Colorado Fuel and Iron Corp. was the most interesting part of the Rocky Mountain Section's April 16 tour of that company's installation. The mill moulds and rolls solid steel billets into seamless tubing.

While the Section watched, oil well casing, 12 inches in diameter, was rolled. Although it appeared that the hole in the tube is punched out by a mole-like mandrel, it is actually formed by being rolled over the piercer point, a center-punch of sorts. Thick-walled and undersize when it leaves the piercing operation, the tube is sized, wall thickness adjusted, straightened, and re-sized to specifications, in a series of operations. Gaging of the walls is done with an X-ray.

In addition to the seamless tube mill, the Section also watched a furnace tap of the open hearth furnaces, and followed the steel ingots to the rail mill where the blooming mills were in operation—an operation of particular interest to the chemical engineers.

—R. M. Berry


*Where you need*

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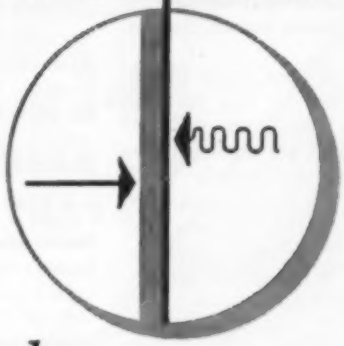
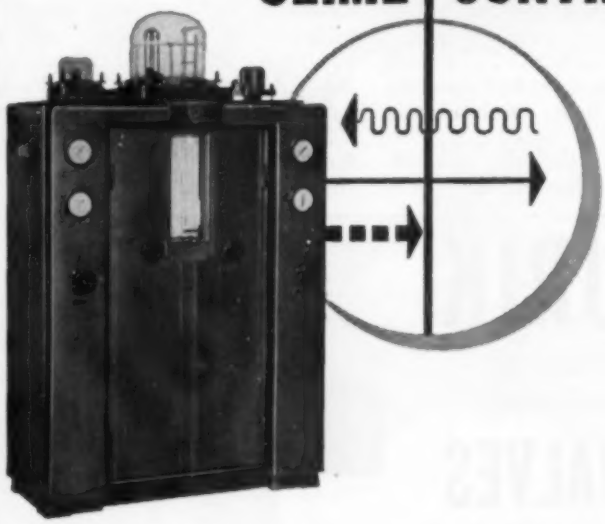


*Be sure you have*

**SLIME | CONTROL**



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## News of the Field
### FROM LOCAL SECTIONS

**Pittsfield, Mass.** Effects of polymer irradiation were described by A. M. Bueche, General Electric, at the meeting of the Western Massachusetts Section on May 10.

Bueche explained that when a substance is bombarded by any form of x-ray or electron that gives sufficient energy to give good penetration, there is a disruption of the molecular structure to give both polymerization and degradation. When the rate of cross-linking is faster than that of degradation, the material's properties are improved. A simple rule of thumb indicates that when a substance has an alpha hydrogen on a carbon adjacent to the characteristic side group, there is polymerization. Such substances as polystyrene, polyester, nylon, butadiene, polyethylene, and natural rubber are cross-linked, and materials such as Teflon, Kel-F, polyisobutylene, and polymethyl methacrylate are degraded. The amount of cross-linking is dependent upon the time of exposure under the irradiating beam.

Because of its relatively high efficiency in cross-linking, polyethylene is the first substance that has benefited commercially from irradiation. Irradiated polyethylene, like conventional polyethylene, is tough, moisture resistant, and chemically inert. Unlike conventional polyethylene, it does not melt at temperatures as high as 350° F., and is resistant to stress cracking. The tensile strength is also improved by irradiation. The amount of irradiation needed to produce these properties is inversely proportional to the initial molecular weight of the polyethylene, but is independent of the rate of irradiation.

—H. WALLMAN

**Washington, D. C.** Management cannot make risky capital safe, but it can make safe capital less expensive. This was one of the ideas expressed by R. P. Soule, Irving Trust Co., at a panel discussion on finance in the process industries held on April 25 by the National Capital Section. Other panelists in the program were V. R. Bechtel, American Cyanamid; Newton Steers, Atomic Development Mutual Fund; and Carl Flesher, World Bank. Panel moderator was E. C. Acheson of George Washington University.

Soule pointed out that the cheapest form of capital (funded debt) is the riskiest for a business to obtain, holds definite obligation to pay fixed interest charges, ultimately to return the principal to the investor. On the other hand, the most expensive form of capital (common equity) is the safest, involves no fixed obligation for repayment. Therefore, the safer a business, the more readily it can be financed by borrowed capital. If a business is itself risky, it must lean most heavily on common equity financing.

In 1954 average cost before taxes of borrowed capital was 3½% for 20 leading chemical companies. For preferred stock, equivalent cost was 8½%; for common equity capital, 12¾%. Low cost debt is suitable for financing relatively safe projects, such as process improvements. More hazardous ventures, including the development of new products and processes, call for common equity. When the investment quality of a company is high, as may be indicated by a high price-earnings ratio for its common stock, equity capital is correspondingly of relative low cost. Thus with the better quality chemical companies, cost of common stock may not be much greater than that of debt capital. Good management, therefore, can lead to new financing that is both safer and comparatively inexpensive.

—D. M. KIEFER


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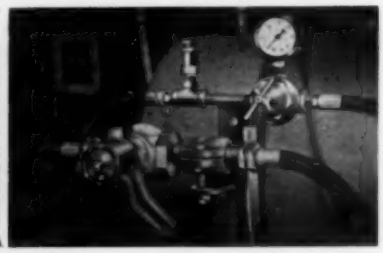
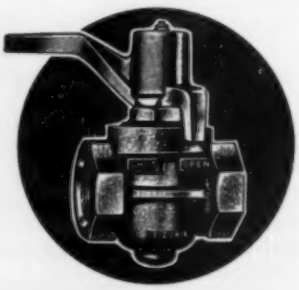


Fertilizing units like these are applying both non-pressure and low-pressure liquid nitrogen solutions to millions of acres of farm land across the country. The manufacturer of this unit selected aluminum DeZurik Valves as the master shut-off for his equipment. They last longer, require no lubrication—virtually no maintenance—they open or close with an easy quarter-turn, and they don't leak!

The versatility of DeZurik Valves is demonstrated day after day in a wide variety of applications. From paper mills to water works, from farm lands to oil fields, DeZurik Valves are on the job!



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**Amherst, Mass.** In a culture becoming more and more technologically oriented the role of engineers as citizens is growing increasingly important. They should use their knowledge in maintaining taste, form, and lasting value in the vacuum of an exploding culture rather than be bystanders or highly trained instruments for production and research, said D. W. Rogers, Univ. of Mass., at the joint April meeting of the Western Massachusetts Section and the University Student Chapter.

There is a tendency, Rogers pointed out, for engineers and scientists to seek retreat from social confusion and uncertainty in the more calculable environment of their profession. With their special knowledge, however, they must share responsibility for the direction taken by technological advances of their creation. Citing as examples some instances of inferior and unsafe workmanship offered to unsuspecting consumers, it was suggested that engineers have a moral responsibility in prevention of these practices, taking a greater part in consumer education regarding potentials and limitations of goods and services offered.

Until recently engineering education has been too narrow. This trend has reversed recently at many institutions, with more emphasis placed on basic scientific knowledge and application of scientific thought techniques to other fields of endeavor. The talk was followed by a discussion period in which engineers and students actively participated.

Second highlight of the evening was the presentation of an A.I.Ch.E. award for excellence in the first two years of Chemical Engineering work to R. A. Bochman, a senior at the University. The award consisted of a certificate, plaque and a two-year subscription to *Chemical Engineering Progress.*

—C. H. FAWKNER

**El Dorado, Ark.** Principals and applications of the mass spectrometer, infra-red spectrometer, spectrometer, ultraviolet analyzer, differential refractometer, and the low concentration oxygen analyzer, were explained by Maynard Perry, Consolidated Engineering Co., Dallas, at the April 22 meeting of the El Dorado Section.

Main points of Maynard's talk covered the application of these physical means of analysis to plant control problems.

—W. L. BREAK

**Rochester, N. Y.** Change of pace from daily engineering problems for the Rochester Section was its annual banquet on May 25. Speaker was famous Countess Maria Pulaski, talking on "My Life As A Spy."

—D. KRAYBILL

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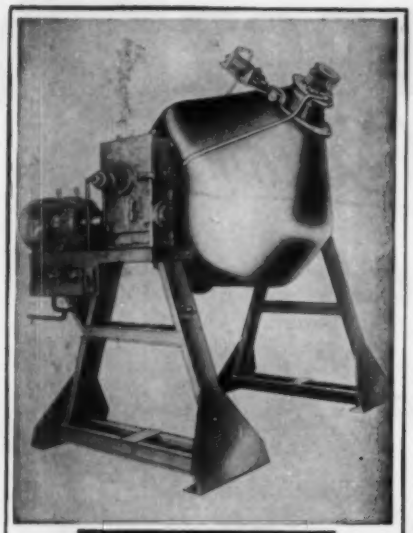

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# CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before May 15, 1955, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

## Member

Aronson, David, *New York, N. Y.*
Browne, Robert Y., *Louisville, Ky.*
Brownell, L. E., *Ann Arbor, Mich.*
Churchill, Stuart W., *Ann Arbor, Mich.*
Coleman, Leonard W., *Houston, Tex.*
Critcher, Harold G., *Hopewell, Va.*
Daniels, George H., *South Charleston, W. Va.*
Dolan, T. J., *Beverly, Mass.*
Granger, F. L., *Cleveland, Ohio*
Harrison, Albert N., *Wilkinsburg, Pa.*
Heinze, Marvin C., *Rahway, N. J.*
Hillard, George O., *Jr., Baton Rouge, La.*
Hiserodt, Richard A., *Syracuse, N. Y.*
Hoots, Richard B., *Jr., Newark, Del.*
Hunter, Seaton, *Texas City, Tex.*
Jones, Don E., *Independence, Mo.*
Kubie, William L., *Evergreen Park, Ill.*
Leggett, C. W., *Monterey Park, Calif.*
Lewis, Allen L., *Houston, Tex.*
Lewis, George R., *Old Hickory, Tenn.*
Luby, William K., *La Grange, Ill.*
Mayfield, Lewis G., *Bozeman, Mont.*
Neas, Charles C., *South Charleston, W. Va.*
Nicolai, Lloyd A., *Baton Rouge, La.*
Peruzzi, Robert V., *Cheltenham, Pa.*
Reeves, Adam A., *Rifle, Colo.*
Reynolds, David G., *Whittier, Calif.*
Rucker, Glenn D., *El Dorado, Ark.*
Scott, V. L., *Freeport, Tex.*
Shaw, James H., *Charleston, W. Va.*
Sifferd, Robert, H., *Joliet, Ill.*
Sparks, Archie G., *Jr., Wilmington, Del.*
Spengler, William E., *Toledo, Ohio*
Stowell, Edgar D., *New York, N. Y.*
Stults, F. C., *Richmond, Va.*
Thayer, Harold E., *St. Louis, Mo.*
Tyler, C. E., *St. Simons Island, Ga.*
Watson, Frank Graham, *Houston, Tex.*
Williams, William, *Toledo, Ohio*

## Associate

Baker, Marshall E., *Army Chemical Center, Md.*
Batke, T. L., *Amherst, Mass.*
Bell, Kenneth J., *Richland, Wash.*
Blanke, Donald L., *Prairie Village, Kan.*
Boland, Roy, *Newark, N. J.*
Boyd, Carter C., *Indianapolis, Ind.*
Brink, Richard H., *Fort Worth, Tex.*
Brown, N. H., *Corpus Christi, Tex.*
Bryan, William L., *Philadelphia, Pa.*
Butler, Gerard, *Stamford, Conn.*
Chamberlin, Roger S., *Freeport, Tex.*
Chang, Pin, *Urbana, Ill.*


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*Write for Bulletin 13-F, Tower Packing*

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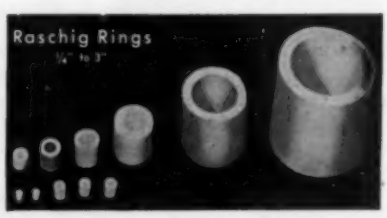

Chase, Robert C., *Orono, Me.*
Clark, Robert G., *New Orleans, La.*
Clinkenbeard, William L., *Roselle, N. J.*
Clinton, William P., *Hoboken, N. J.*
Costello, Walter H., *Langhorne, Pa.*
Craig, Jack H., *Belle, W. Va.*
Cram, Michael J., *Crestwood, Mo.*
Dagher, Anis N., *Beirut, Lebanon*
Dawson, John, Jr., *Midland, Mich.*
Duncan, Dewitt, Jr., *Pampa, Tex.*
Eichhorn, Emil, *Brooklandville, Md.*
Eilers, Robert D., *Harvey, Ill.*
Eriksen, E. B., *Neodesha, Kan.*
Finch, Charles R., *Wright-Paterson A.F.B., Ohio*
Fletcher, David M., *Pitman, N. J.*
Gaven, Joseph V., Jr., *Arlington, Va.*
Gebhard, Donald H., *Denver, Colo.*
Gestrich, William R., *Verona, Pa.*
Golante, David, *Westfield, N. J.*
Gumaer, R. R., *New Orleans, La.*
Gunder, Pierre F., *Yonkers, N. Y.*
Haddick, John S., *Chicago, Ill.*
Hanley, William R., *New York, N. Y.*
Harman, Carl A., *St. Albans, W. Va.*
Hern, Clinton H., *New York, N. Y.*
Hittner, Herman J., *Pittsburgh, Pa.*
Hou, Y. C., *East Lansing, Mich.*
Hrubes, E. James, *Penns Grove, N. J.*
Huber, James A., *Medina, Ohio*
Jonic, C. A., *Pittsburgh, Pa.*
Kaneko, Thomas M., *Salt Lake City, Utah*
Kivlin, Howard F., *Brooklyn, N. Y.*
Knight, B. D., *Port Arthur, Tex.*
Kuhman, Clement A., *Cleveland, Ohio*
Kuloor, N. R., *Delhi, India*
Langel, Robert J., *Wilmington, Del.*
Legler, Billy M., *Idaho Falls, Idaho*
Lentz, Billy J., *Baton Rouge, La.*
Lerner, Joshua E., *Lake Charles, La.*
Malkin, E. Steele, *Westfield, N. J.*
Mansfield, Robert F., *Pittsburgh, Pa.*
Maxwell, Donald O., *Cleveland, Ohio*
McManus, Joseph C., Jr., *Charleston, S. C.*
Michels, Frank G., *Brooklyn, N. Y.*
Miller, Archie P., *Monroe, La.*
Moser, J. F., Jr., *Baton Rouge, La.*
Nicholas, John S., *South Charleston, W. Va.*
Pearson, Allen D., *Albert City, Iowa*
Quirk, Robert F., *Schenectady, N. Y.*
Reidinger, Raymond C., *Wilmington, Del.*
Rhodes, Thomas H., *Baton Rouge, La.*
Schechter, Stanley J., *Elkins Park, Pa.*
Shaw, B. C., *Kansas City, Mo.*
Shaw, K. Glenn, *Pleasant Hill, Calif.*
Shivalingiah, B., *West Lafayette, Ind.*
Shurts, Edward L., *Wilmington, Del.*
Smith, Sam W., *Houston, Tex.*
Smutney, Robert R., *Waukegan, Ill.*
Soule, Edward L., *Berkeley, Calif.*
Stallings, Vincent P., *Niagara Falls, N. Y.*
Stein, Ralph P., *New York, N. Y.*
Stice, James E., *Fayetteville, Ark.*
Templeton, William J., *Bartlesville, Okla.*
Troeltzsch, L. A., *Texas City, Tex.*
Valdes, Antonio R., *Houston, Tex.*
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# FUTURE MEETINGS and Symposia of the Institute

*Note: The Author Information column will appear quarterly in the January, April, July and October issues.*

**MEETINGS** **SYMPOSIA**

■ **LAKE PLACID, N. Y.**

Sept. 25-28, 1955. Lake Placid Club.

A meeting devoted to the problems of interest to top management.

NOTE—No general papers

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Mgr. Proc. Engr., Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

**Chemical Engineering Organizations of the Future**

CHAIRMAN: J. F. Thornton, Pres., The Lummus Co., 385 Madison Ave., New York 17, N. Y.

**Growth of the Oil & Chemical Industry by Integration**

CHAIRMAN: F. M. Simpson, Vice-Pres., Petroleum Chemicals Inc., 54 Wall St., New York 5, New York

**Packaged Power**

CHAIRMAN: H. Arthur Martin, Exec. Vice-Pres., J. F. Pritchard Co., Kansas City, Mo.

**Social Responsibilities**

CHAIRMAN: James Donovan, Pres. Artisan Metal Products, Inc., 73 Pond St., Waltham 54, Mass.

**Deadline Past**

**Atom Profits**

CHAIRMAN: W. Kenneth Davis, Reactor Dev. Div., U. S. Atomic Energy Comm., 1901 Constitution Ave. N.W., Wash., D. C.

**MEETINGS** **SYMPOSIA**

■ **ANNUAL—DETROIT, MICH.**

Nov. 27-30, 1955. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

**Experiences in Nuclear Engineering**

CHAIRMAN: R. P. Genereaux, Eng. Dept., Dupont Co., Wil., Del.

**Biochemical Engineering**

CHAIRMAN: H. O. Halvorsen, Dept. of Bacteriology, Univ. of Illinois, 362 Noyes Lab. of Chem., Urbana, Illinois.

**Technical Societies Cooperation with Chemical Engineering Industries**

CHAIRMAN: J. B. Phillips, Dept. Chem. Eng., Phys. Sciences Centre, McGill Univ., Montreal 2, Canada.

**Mechanics of Bubbles and Drops**

CHAIRMAN: R. C. Kintner, Dept. Chem. Eng., Ill. Inst. of Tech., 3300 Federal St., Chicago 16, Ill.

**Standardization of Centrifugal Chemical Pumps**

CHAIRMAN: C. J. B. Mitchell, Engineering Service Div., Engin. Dept., E. I. duPont deNemours Co., Inc., Wil., Del.

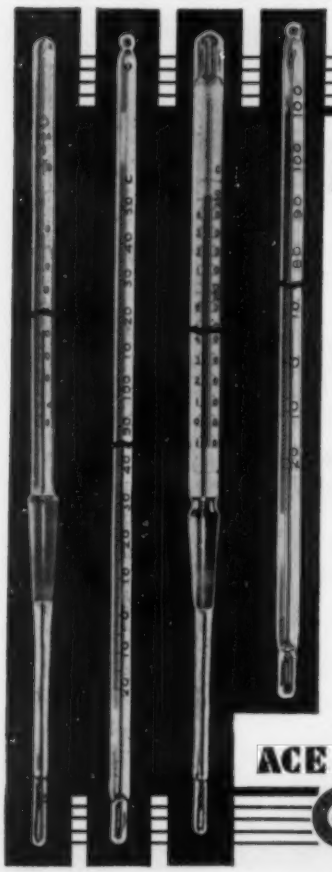
**Evaporators**

CHAIRMAN: W. L. Badger, 309 S. State St., Ann Arbor, Mich.

**Liquid Metals in Chemical Industry**

CHAIRMAN: C. F. Bonilla, Dept. of Chem. Eng., Columbia U., N. Y. 17, N. Y.

*Deadline—July 27, 1955*

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**MEETINGS** **SYMPOSIA**

■ **LOS ANGELES, CALIF.**

Feb. 26-29, 1956. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

**New Techniques for Utilization of Fast Reactions & Freezing of Equilibria**

CHAIRMAN: W. H. Corcoran, Cal. Inst. of Tech., 1201 E. Cal. St., Pasadena, Cal.

**Current Status of Completely Automatic Process Units**

CHAIRMAN: F. C. Brunner, C. F. Braun & Co., 1000 S. Fremont Ave., Alhambra, Cal.

**Supervision of Technical Personnel (Panel)**

CHAIRMAN: R. D. Gray, Cal. Inst. of Tech., 1201 E. Cal. St., Pasadena

**Techniques of Economic Justification for Process Industry Projects**

CHAIRMAN: H. E. Wessel, Interna'l. Minerals & Chem. Corp., 20 N. Wacker Dr., Chicago, Ill.

*Deadline—Oct. 26, 1955*

■ **NEW ORLEANS, LA.**

May 6-9, 1956

TECHNICAL PROGRAM CHAIRMAN: H. E. O'Connell, Assoc. Dir. Process Div., Sect., Ethyl Corp., Box 341, Baton Rouge, La.

■ **PITTSBURGH, PA.**

Sept. 9-12, 1956

TECHNICAL PROGRAM CHAIRMAN: Carl C. Monrad, Carnegie Institute of Technology, Pittsburgh, Pa.

■ **ANNUAL—BOSTON, MASS.**

Dec. 9-12, 1956. Hotel Statler.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

*Deadline—August 9, 1956*

**UNSCHEDULED SYMPOSIA**

**Extraction of Hydrocarbons for Chemical Use from Pipeline Gases**

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

**Distillation Computation Methods**

CHAIRMAN: Wayne C. Edmister, California Res. Corp., Richmond, Calif.

■ **GALVESTON, TEXAS**

October 14, 1955. Galvez Hotel

One-day Technical Meeting of the South Texas Section (10th Annual).

CHAIRMAN: W. L. Bolles, Monsanto Chemical Co., Texas City, Tex.

PROGRAM CHAIRMAN: Earl Manning, Shell Oil, Houston, Tex.

■ **CLEVELAND, OHIO**

Dec. 12-17, 1955. Cleveland Auditorium.

**EJC Nuclear Eng. & Science Congress**

PROGRAM CHAIRMAN (A.I.Ch.E.): W. K. Woods, General Electric Co., Richland, Wash.

**Liquid Metals in Nuclear Power**

CHAIRMAN: C. F. Bonilla, Dept. of Chem. Eng., Columbia U., N. Y. 17, N. Y.

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# people

## IN MANAGEMENT AND TECHNOLOGY

**William I. Burt,** past president of the A.I.Ch.E., was honored at the Second Annual Conference for Engineers and Architects at Ohio State U., College of Engineering as the recipient of one of five Distinguished Alumnus awards.

The award is given by the College as its highest tribute to alumni who have "attained records of outstanding eminence in engineering and related activities of industry and defense."

Burt is president of Goodrich-Gulf Chemicals, Inc. He is a 1917 graduate in chemical engineering from Ohio State. His career and service record include the position of vice-president-manufacturing with B. F. Goodrich Chemical Co. and vice-president and director of the A.I.Ch.E. He is the recipient of several other awards in recognition of his work in the synthetic rubber industry.

**Robert D. Scott** succeeds Burt as vice-president-manufacturing of B. F. Goodrich Chemical Co.

Scott, former general manager of plants, earned his master's degree in chemical engineering in 1935 from M.I.T. He joined Goodrich as an engineer that year.

**Raymond A. Erickson** is named supervisor of the newly-established engineering economics research dept. at Armour Research Foundation of the Ill. Institute of Technology.

Erickson, who joined the Foundation in 1953, also serves as supervisor of the chemical engineering research section.

The new department combines the efforts of scientists, engineers, and economists in solving a variety of industrial problems.

*(Continued on page 94)*


# NEWS from FILTERTOWN

A recent survey establishes that clarity of filtration is the most important factor in the selection of a filter medium. Since E&D filter papers give the "finest" filtration, more E&D filter papers are used by industry than the total of all other filter papers combined . . . To cite but a few applications: grades 609 (WINE-BRITE) and 902 (*BREW-BRITE®) are widely used in filtration of alcoholic beverages; 623 is extensively used for filtration of chemicals; 615 and 617 for foods and beverages; 613 for drugs and toilet preparations; and there are many more . . . This is not to say that any grade is universally used in any specific industry. Too many varying factors make this impossible. That is why E&D 's know-how, based on the practical experience of many decades, enables us to help you select the right grade for your particular assignment . . . Moreover, this is the only company in America exclusively engaged in the manufacture of filter paper for science and industry. There are many regular grades and special grades available. You can rely on any E&D filter paper to perform as recommended. Why take a chance on unidentified papers? The cost in loss of time and money can be serious . . . Write for free samples. Test them. Discover why E&D filter papers are used exclusively by most of America's leading industries . . . If you have a bothersome filtration problem write for our free Filtration Analysis Report. Chances are we know the answer . . . Used alone, or with cloth, there's an E&D filter paper to give you clarity of filtration and savings in time, labor and money.

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**Clifford C. Burton** moves to the manufacturing division of C. E. Braun

JUNE 1955

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*Published by the American Institute of Chemical Engineers*

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# people

## IN MANAGEMENT AND TECHNOLOGY

(*Continued from page 93*)

**George E. Holbrook,** a director of the A.I.Ch.E., is named assistant general manager of DuPont's organic chemicals dept., in addition to his present position of assistant director of the development dept.

With DuPont since 1933, Holbrook has contributed his experience and efforts in various capacities in the organic chemicals dept., as head of the new products division, and as assistant director of the Jackson Lab, moving then to development superintendent of the Chambers Works and other managerial spots before assuming his present positions.

Holbrook earned three degrees in chemical engineering, including his doctorate, at the U. of Michigan. He was the 1953 recipient of the Institute's Professional Progress Award.

---

**Norman Kirk** is manager of the chemical process research section, General Electric Research Lab.

Kirk joined the lab in 1947 from Penn State where he had received his doctorate degree in 1946. He had been a faculty member of that school from 1943. He succeeds A. E. Schubert.

---

**T. J. Carron,** technical program chairman for the 1955 annual meeting of the A.I.Ch.E. in Detroit, becomes director of employee training and development in the Ethyl Corp.

Carron will be responsible for training and development of all professional employees and will head the administration of the company's university fellowship program.

---

**Bruce Nanney** branches out from his engineering career to become mayor of Canton, N.C.

Nanney, an active member of the Institute, is assistant superintendent of the electrolytic bleach dept. at Champion Paper & Fibre Co. in Canton.

**Clifford C. Burton** moves to the manufacturing division of C. F. Braun & Co. as manager. He will headquarter in Alhambra, Calif.

Burton had been district engineer and district manager with the company in New York.

Before joining C. F. Braun, Burton was senior engineer in the refinery engineering dept. of the Texas Co., having taken this position after his graduation from Calif. Institute of Technology.

---

**Brig. Gen. Stewart E. Reimel** (ret.) has resigned as Secreary of Engineers Joint Council.

The Council, in a resolution expressing regret on the resignation of Reimel, stated that "the wise guidance and skillful diplomacy of General Reimel have contributed greatly to the development and prestige accorded EJC."

Reimel, who will continue as Secretary of the EJC Committee on International Relations, is succeeded as Secretary of the Council by E. Paul Lange.

---

With many years' experience as a design engineer for several of the country's leading manufacturers of heat transfer equipment, **Donald Q. Kern** is appointed professional consultant in heat transfer at Wolverine Tube, division of Calumet & Hecla, Inc.

---

**Olaf A. Hougen**, professor of chemical engineering in the College of Engineering at the U. of Wisconsin, earned the first annual Benjamin Smith Reynolds Award given by the University for excellence in teaching of future engineers.

---

Diamond Alkali Co. names **Robert J. Koll** plant manager of the Greens Bayou Plant, Houston. **William J. Lightfoot** is promoted by the company to chief staff engineer in the central engineering dept.

Both men are graduate chemical engineers of Case Institute of Technology.

---

**Charles H. Fox** joins the Glenn L. Martin Co. in the nuclear division as a senior engineer.

---

In a recent announcement of managerial changes, Koppers Co. named **W. B. Jackson** assistant production manager, tar products division.

(*Continued on page* 96)


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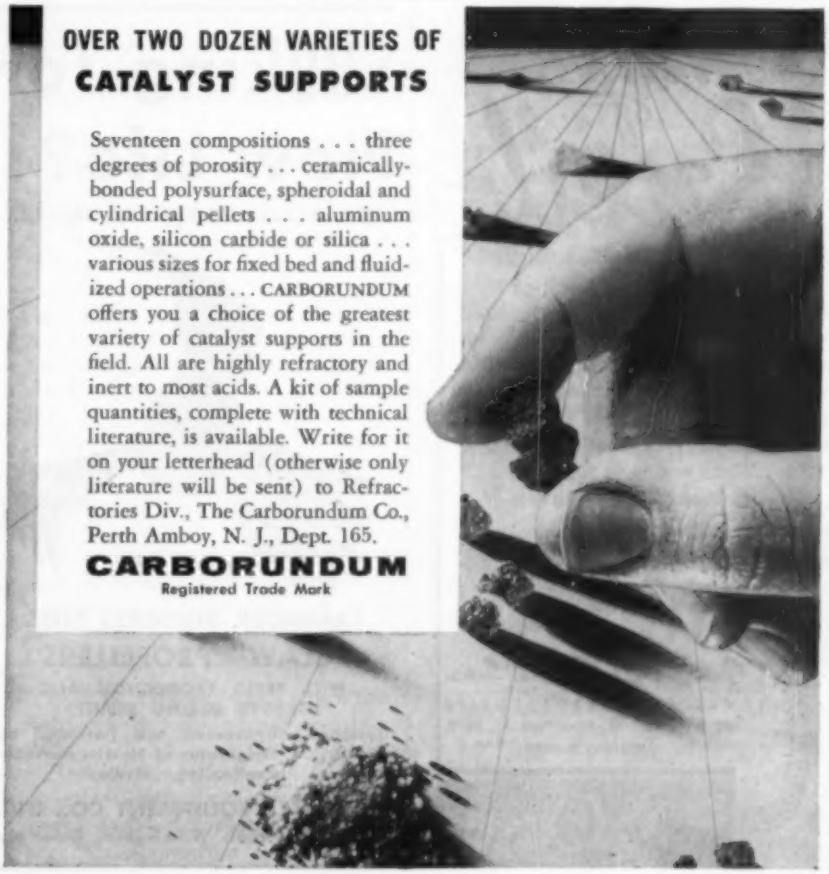

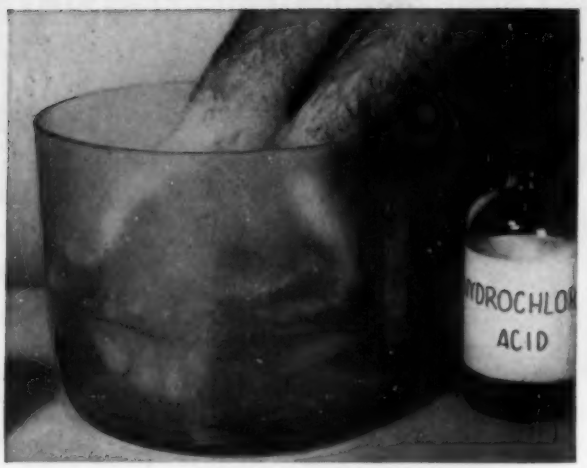


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**FOR YOUR PROPELLER MIXERS**

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**WILL SPEED PRODUCTION AND IMPROVE MIXING RESULTS**

**Designed, Engineered and Patented by CRADDOCK, Originator of Electric Portable Propeller-Type Mixers**

**CRADDOCK EQUIPMENT CO., INC.**
**1507 "A" Street, Wilmington, Delaware**


# people

## IN MANAGEMENT AND TECHNOLOGY

(*Continued from page* 95)

**George Granger Brown,** treasurer of the A.I.Ch.E., was recently honored by the New York U. College of Engineering, with the degree of doctor of engineering.

Brown, who is an alumnus of the NYU College of Engineering, serves as dean of engineering at the U. of Michigan.

In the citation accompanying the award, NYU Chancellor Heald described Brown as a "distinguished educator and engineering scientist."

**J. Henry Rushton** is appointed professor of chemical engineering at Purdue U. He will assume his new position in September.

Rushton, a past director of the A.I.Ch.E. and an active member of several committees, is the author of more than 50 technical and professional papers and co-author and contributor to several books. He was once recipient of the Institute's Walker Award.

Rushton is a graduate with the doctorate degree from the U. of Pennsylvania.

He was recently elected to the office of non-resident vice-president of the Chemists' Club, N. Y. at that group's 56th annual meeting.

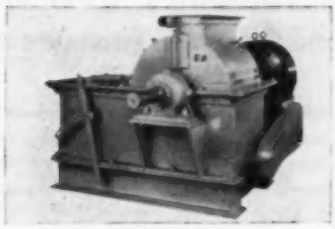
**William P. Gage,** formerly president of Grace Chemical Co., is head of a newly-established division of W. R. Grace & Co.

The new organization, known as the Grace Chemical Research & Development Co. division, is intended as a spearhead to the company's anticipated further expansion in chemical manufacturing and processing.

**Elwyn E. Winne** is named vice-president of the new division.

**Donald A. Limerick** is appointed assistant superintendent in charge of butadiene and styrene production in the Torrance, Calif. plant of Shell Chemical Corp.

PROCESSING MACHINES, SINCE 1885



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**THE GRUENDLER No. 24 TURBO-HOMOGINIZER**

*Used to prepare filter aids and for preparing pulps for diffusions and extractions. For reclaiming and refining wood wastes, agricultural fibres, bagasse, straw, flax, cotton linters and the like.*

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*Announcing a New Process and a New Service*

**ARCHED WAFERS OF YOUR PRODUCT**

***Many advantages over flakes or other shapes***

**For further information about our CONFIDENTIAL SERVICE, address:**

**FLAKICE CORPORATION**
**360 Furman Street**
**Brooklyn 1, New York**

## the chemical engineer in MARKETING

**Frank J. Smith** is elected vice-president and general sales manager of Pan American Chemicals Corp.

Smith, previously manager of the petrochemical division of the American Oil Company, graduated as a chemical engineer from the U. of Illinois. He joined American Oil as assistant director of research in Texas City.

The new corporation which he heads will market petrochemicals manufactured in the Texas City plant of American Oil. Smith will continue to headquarter in New York.

---

**Jerome T. Coe,** M.I.T. chemical engineer, becomes sales manager of the silicone products department at General Electric.

Coe joined GE in the research lab after his graduation in 1942 from M.I.T. After an interim in the Navy during World War II, he returned to GE and worked in the chemical division and then at the silicone plant, where he received his present appointment.

---

Spencer Chemical Co. names **Mark B. Stringfellow** manager of market development.

Coming to Spencer from the position of manager of the plastics division at Nopco Chemical Co., Stringfellow has experience also from development and engineering work with Carbide and Carbon and in the Army's biological warfare program at the atomic energy installation at Oak Ridge and Paducah, Ky.

Stringfellow is a chemical engineering graduate of the U. of Texas.

---

**James R. Harrington** moves to Chicago as assistant district manager of sales for the inorganic chemicals division of Monsanto Chemical Co.

Succeeding Harrington as district sales manager in Cincinnati, is **Lester D. Hatch.**

---

**Earl W. Loucks** joins Thiokol Chemical Corp. as technical sales representative.

He will engage in sales of polysulfide liquid polymers, plasticizers, and oil and solvent-resistant synthetic rubbers.

(*Continued on page* 101)

**KILL IT** *with a*
**DOW CORNING SILICONE DEFOAMER**

Use the space now wasted on foam to increase your output by as much as 100%. For example:

- **production of vacuum concentrated food product increased by 60%**
- **refinery still through-put increased from 1500 to 2500 barrels per day**
- **yield of textile vat dyes increased by 100%**

And you get increased production immediately without installing expensive new equipment. All you have to do in the case of most foamers is add a few parts per million of the water dilutable Antifoam AF Emulsion or, where solvents can be tolerated, a dispersion of Antifoam A. Both of these Dow Corning silicone defoamers are physiologically harmless. Both of them **increase production • reduce processing time • eliminate the waste and fire hazard of boil-overs.**

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mail coupon today for
**free sample**

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Midland, Mich., Dept. 3006

Please send me data and free sample of
☐ Dow Corning Antifoam A Compound
or ☐ Dow Corning Antifoam AF Emulsion

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COMPANY_____
ADDRESS_____
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# CLASSIFIED SECTION

Address Replies to Box Number Care of CHEMICAL ENGINEERING PROGRESS

## SITUATIONS OPEN

**PROCESS ENGINEERS**

Openings for chemical engineering graduates with minimum three years' experience in process plant design. Work involves project engineering, equipment application and selection, translation of process data into new plant design. Applicant should be well grounded in thermodynamics, unit operations, and equipment specifications. The work is interesting, salary and opportunities are attractive; location in Texas. Send résumé to Box 1-6, Chemical Engineering Progress and interview will be arranged.

**PROCESS ENGINEER**

Experienced in design, engineering and supervising operations of carbon black plant employing oil black process.

Interviews arranged on basis of complete chronological résumé, including education and employment (names & addresses of employers, dates employed, salaries received, positions held, including your specific duties and responsibility.

All replies are confidential.

**Box 4-6**

## ENGINEERS NEEDED

**CHEMICAL AND MECHANICAL ENGINEERS**

with design, construction and production experience to lead projects through planning, design, construction and start-up operations. Ages 32-38, with a variety of job experiences desirable.

Job is in plant engineering department, working with all divisions (research, development, production, maintenance and purchasing).

Replies will be confidential and should include a recent photograph, together with full details of background, present salary, etc.

CONTACT:

**HIRAM WALKER & SONS, Inc.**

*Personnel Division*

**1616 South Washington Street**

**Peoria, Illinois**

## THE STANDARD OIL COMPANY (OHIO)

MANUFACTURING (REFINING) DEPARTMENT

**is looking for**

**CHEMICAL ENGINEERS,**

**CHEMISTS, and**

**MECHANICAL ENGINEERS**

with one to five years experience in petroleum refining or related activities for staff work primarily in Cleveland, Ohio. Possible employment in Toledo, Lima, or Cincinnati, also.

Applicant should have the following educational background and industrial experience:

*Chemical Engineers:* B.S or higher degree and experience in development, pilot plant operation, process design, process trouble shooting, refinery process engineering, economic studies, or related work background.

*Chemists:* B.S. or higher degree and experience in product and process research or development.

*Mechanical Engineers:* B.S. or M.S. degree and experience in process equipment construction, design, inspection, or maintenance, petroleum product testing and field evaluation, or related work background.

Age range 22 – 32

Salaries commensurate with experience and level in organization. Advance on merit basis.

If you can qualify and are looking for a permanent job with a growing but secure midwest company, write, giving full information on education, industrial experience, military experience, and personal data to E. G. Glass, Jr., 1737 Midland Building, Cleveland 15, Ohio.

## CHEMICAL ENGINEERS

INVESTIGATE
CAREER OPPORTUNITIES
IN

Southern California

with one of the nation's leading engineering firms serving the petroleum and chemical industries. The work is basically process-design, economic evaluation, and application of processes to industry.

Write for our illustrated brochure, *Environment for Engineering*. Please include a brief outline of your education and experience. Your inquiry will be treated in confidence.

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The design of furnaces to improve process service requires exceptional training and ability. We'd say the minimum was an ME or ChE degree, 8 years' background in furnace design, and a thorough knowledge of heat transfer fluid flow, chemical reaction, metallurgy and strength of materials as applied to furnace design.

The ability to recommend desirable process changes, to develop new designs and design methods requires additional talents as well as initiative.

If you can meet these exacting qualifications, we'd like to meet you. The result can be mutually profitable.

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**EXCELLENT OPPORTUNITIES**

In

**PRODUCT AND APPLICATION DEVELOPMENT**

For

**CHEMICAL ENGINEERS**

Unusual career openings in the fields of adsorption, ion exchange and catalysis. Test marketing and customer liaison involved. Men with potential in technical sales may qualify later for responsible field positions.

Industrial experience desirable but not mandatory. Men under thirty preferred with bachelors or masters degree.

*Write, sending résumé and approximate salary requirement, to*

**LINDE AIR PRODUCTS CO.**
a Division of
**UNION CARBIDE AND CARBON CORP.**

*Attention:* Technical Personnel Dept.
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**Metals Research and Development Facilities**
of the
**Electro Metallurgical Company**

*OFFERS OPPORTUNITIES*—Continued expansion of research and development operations provides attractive technical staff openings at Union Carbide's Metals Research Laboratories and Metallurgical Department. This progressive industrial organization offers the qualified scientist a stimulating research environment and challenging opportunities—plus the fine benefit programs which characterize association with the Union Carbide and Carbon Corporation. To the individual who values enlightened research philosophy, splendid experimental facilities and activity on the Frontiers of Metallurgy, Chemical Processing and Associated Scientific Developments, we suggest careful review of the following current openings.

*ENGINEERS FOR CHEMICAL AND METALLURGICAL RESEARCH AND DEVELOPMENT*—Graduate chemical and metallurgical engineers are required to plan, organize and conduct broad experimental and development programs involving process metallurgy and inorganic chemical processes, including design and operation of medium to large scale pilot plants. Will have responsibility for preparation of reports, analysis and interpretation of data and accomplishments of other engineers, cost estimates and economic appraisals. Candidates must have good record of accomplishment and up to ten years of experience.

*METALS RESEARCH CERAMIST*—Plan and conduct research in fields of intermetallics, metalloids, ceramic and metal ceramic materials. Ph.D. or Sc.D. in Metals Ceramics with strong background in Physical Chemistry.

*RESEARCH AND SALES DEVELOPMENT METALLURGISTS (2)*—Scientists to plan and execute experimentation on: (a) titanium and titanium-base alloys; and (b) non-ferrous high-temperature alloys. Design experiments for studying transformations and for generalizing mechanical and physical behavior in terms of structure. Ph.D. or M.S. up to three years' research experience, with training in solid-state transformations and theoretical physical metallurgy.

*SENIOR RESEARCH CHEMIST*—Inaugurate comprehensive research programs to investigate inorganic compounds. Apply strong theoretical and application background in both the preparation and purification of elements and compounds. Ph.D. in chemistry with a minor in physics.

*METALLURGICAL RESEARCH ENGINEERS (2)*—Conduct research with emphasis on: (a) steels and ferrous alloys; and (b) high-temperature thermochemistry and process metallurgy. The steel and ferrous investigations will include fabrication and heat-treatment as well as metallographic studies; and will require a B.S. or M.S. in Metallurgy or Metallurgical Engineering with 1-3 years' experience. The high-temperature thermochemistry research will extend into problems of physical chemistry of steel making, extractive metallurgy and process metallurgy. A Ph.D. in Metallurgical Engineering or M.S. with related experience is required.

*RESEARCH ENGINEER*—Conduct research on mineral and metal extraction problems. Improve methods of mineral recovery, develop process and flow sheet, perform research on comminution, flotation, electrostatic and magnetic separation. Ph.D. or Sc.D. in Mineral Engineering or Metallurgical Engineering.

*CHEMICAL ENGINEER—SUPERVISING DESIGN ENGINEERS*—Capable men to design or supervise design of major structures, buildings, services, and utilities for varying sized projects. Select machinery and equipment; prepare cost estimates, specifications, requisitions; make bid comparisons for equipment purchases and construction costs. When necessary, supervise erection of buildings and installation of machinery, etc., at job site. Five to ten years' experience essential.

**Please send complete résumé to:**
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*Excellent Career Opportunities*

**Packaging Research and Development**

**in the Food Industry**

*Ultimate goal—better living for more people*

**SECTION HEAD responsible for supervising projects covering the study of fundamental packaging principles and the development of new or improved packages for existing products and for new products. Work covers laboratory testing of materials and packages, pilot plant preparation of finished packages, economic evaluation of packaging and start up operations of new packaging lines. Particular emphasis on moisture protection, functional design and cost reduction.**

RESPONSIBLE for the supervision of 12 technologists and technicians in Laboratory, Pilot Plant and field operations. Expansion planned beyond the present level.

**APPLICANT should be in good health—between 30 and 40 years of age—proven ability in laboratory supervision—experience in food industry helpful—advanced degree in Chemical Engineering or Food Technology or equivalent in experience—willing to travel moderately.**

Only applicants with an earning record of $7000 should apply.

**Our personnel informed of this opening**

***Send resume and initial salary desired***

**Strictest confidence observed.**

**BOX 3-6**

# QUALITY CONTROL ENGINEERS

This is your opportunity to affiliate with a Company working in the field of atomic energy. We require the services of men with B.S. or M.S. degrees in Chemistry or Chemical Engineering. Training and experience in statistical quality control procedures necessary.

Three to five years' industrial experience in production or quality control work desired.

Our Company offers opportunity for rapid advancement, plus an outstanding program of benefits for employees.

**MOVING EXPENSES PAID**

Address Résumé of Education and Experience to
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## National Lead Co.

**OF OHIO**

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# ENGINEERS

▶ **INSTRUMENT ENGINEER, BSEE,** specializing in electronic circuits and instrumentation. Five years' experience. Project responsibility for design and development of special electronic devices and instruments required by staff of research chemists and engineers.

▶ **PROJECT ENGINEER, BSME,** five years' experience in machine or process equipment design and construction. To determine requirements and to develop specifications and design of equipment required by staff of research chemists and engineers.

The continuing growth of the Celanese Corporation in the textile, chemical and plastics industries creates openings for qualified men in the Research Laboratory located in Summit, New Jersey, a pleasant residential community within 30 miles of New York City. These positions are permanent, and provide excellent opportunity for personal growth and advancement.

***Please write complete details, including salary requirements, to Mr. J. A. Berg.***

Celanese

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# CHEMICAL ENGINEERS

LEADING MANUFACTURER OF HEAVY CHEMICALS REQUIRES CHEMICAL ENGINEERS WITH TWO YEARS' EXPERIENCE. OPPORTUNITY FOR MAN WITH ENERGY AND ABILITY. MAIL RÉSUMÉ, SALARY EXPECTED, AND RECENT SNAPSHOT TO PERSONNEL DIRECTOR, P. O. BOX 3269, TAMPA, FLORIDA.

**ACADEMIC POSITION.**—Chemical engineer, age forty or younger, Ph.D. preferred, extensive and responsible industrial experience required, to fill vacancy in department of Midwestern university for Fall, 1955. Some specialization in metallurgy desirable but not necessary. Rank and salary depending upon qualifications. Give full particulars including personal data, training, experience, publications, references. State salary requirements. Include recent snapshot. Box 5-6.

**CHEMICAL ENGINEER** — Excellent opportunity for your chemical and/or metallurgical engineer who is interested in technical sales, selling engineered items to the petroleum and chemical industries for a manufacturer with nation wide sales organization. Reply to Box 6-6.

**CHEMIST,**—chemical engineering, college graduate, three years' experience in position involving chemical analysis of water. Salary $326 to $435. Civil Service Department, City of Dallas, Dallas, Texas.

**ASSISTANT PROFESSOR OF CHEMICAL ENGINEERING** — appointment September 1955, Ph.D. necessary, salary dependent on experience, opportunity for research and industrial work. Apply to: R. M. Hubbard, Department Chemical Engineering, University of Virginia, Charlottesville, Va.

**CHEMICAL ENGINEER**—M.S. level with background in diffusional operations. Excellent growth opportunity with research and development organization in the application of ultrasonics to chemical process problems. AEROPROJECTS INCORPORATED. WEST CHESTER, PENNSYLVANIA.

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**TEACHING**—Qualified by experience, inclination and personality. M.Ch.E. Fourteen years' industrial especially petroleum refinery process design, economics, technical service. Married and children. Résumé and references on inquiry. Box 8-6.

**PRODUCTION SUPERVISOR**—B.Ch.E. 1947, age 32, married. Eight years' varied experience heavy chemicals production, multi-department administration and organization, cost reduction, plant start-up, process development. Present position, area superintendent. Desire position with administrative responsibility. Box 9-6.

**EUROPE**—B.S.Ch.E. Age 26, single. Four years' experience in production supervision, construction, start-up work in coal tar chemicals field. Strong maintenance and trouble shooting background. Box 10-6.

**PROJECT ENGINEER**—degree, approximately six years' experience in pilot plant, development, operations and chemical plant design. Engineering work wanted in New York City or within 125 miles of New York City. Salary desired $600 per month. Box 11-6.

**CHEMICAL ENGINEER**—B.Ch.E. 1952. Two years' experience in design and development of chemical-ordnance items. Half-year production, control, process improvement and development. Familiar with government contracting. Veteran, age 25, single. Will relocate. Box 12-6.

**B.S. 1952**—Two years' experience in polymer research and development. One year distillery production supervision. Desire position fully utilizing engineering training. Prefer chemical plant design, instrumentation or maintenance. Age 28, veteran, married, family. Box 13-6.

**BOSTON** location wanted by chemical engineer. Four years' experience on consulting staff of large airplane company. Special abilities in heat transfer, flow of compressible fluids, technical writing. Box 14-6.

**CHEMICAL & METALLURGICAL ENGINEER**—P.E., age 32, married, veteran. Five years' experience translating development information into full scale plant designs for midwest chemical company. Desire similar position. Box 15-6.

**CHEMICAL ENGINEER**—B.S. 1951, M.I.T. Minor business administration, age 28, married. Four years' high temperature pilot plant research and development. Desire administrative work offering increasing responsibilities. Box 17-6.

**CHEMICAL ENGINEER**—B.S.Ch.E. Eight years' experience natural and synthetic rubber and latices. Development and compounding. Five years general manager small plant. Adaptable, aggressive, capable of assuming responsibility. Interest includes sales aspects. Midwest. Family. Box 18-6.

**CHEMICAL ENGINEER**—B.S. Ten years' progressive experience. Production, engineering, development, research, adminstration. Business training. Challenging position, with future, major requirement. Excellent record. Age 34, family. Box 19-6.

**CHEMICAL ENGINEER**—B.Ch.E. 1951. Married, veteran. Two years' process piping design, two years' pyrotechnic and armament production. Desire position in New York or vicinity, offering good future. Box 20-6.

**CHEMICAL ENGINEER**—B.Ch.E., 1952, age 24. Separating from Army in June 1955. One year experience as process design engineer for leading contracting outfit. Desire permanent position with expanding oil or chemical company. Box 21-6.

**CHEMICAL ENGINEER**—B.A. and B.S.Ch.E. 1952, Rice Institute, five year engineering program. Age 25, married. Completing three years' Naval service with expected release August 1955. Prefer position in production. Box 22-6.

**CHEMICAL ENGINEER**—Eleven years' diversified experience in petrochemicals, petroleum refining, synthetic fuels, and ammonia with emphasis on process design, economic evaluations, cost studies, and company diversification activities. Present assignment as assistant to executive at salary of $10,000 per year. Seek position with aggressive oil or chemical company. Box 23-6.

**CHEMICAL ENGINEER**—Age 35, ten years' industrial experience in catalytic oxidation, product development, technical service and pilot plant design in coal tar and allied chemical industry, desires supervisory technical position with progressive organization. Preferred location: New England, Southern or Western States. Box 24-6.


**FOR PROGRESS —**

use *Chemical Engineering Progress.*

C.E.P. Classified Section is the answer to the age-old question of where to *get the best* in chemical engineers.


## the chemical engineer in MARKETING

(*Continued from page 97*)

**Henry T. Sharpe** will represent Kawecki Chemical Co. of Pennsylvania in the New York and New England areas in sales of products including titanium, zirconium, lithium, and other alloys and industrial chemicals.

Sharpe is an Iowa State chemical engineering graduate and was associated for six years with the U. S. Atomic Energy Comm. He had been connected with atomic energy research at the Ames Lab prior to his joining the A.E.C.

---

With experience in the research and development department of Shawinigan Chemicals, Ltd., and in subsequent development positions, **James A. McCoubrey** joins North American Cyanamid, Ltd. as manager of the newly formed market research department.

With headquarters in Toronto, McCoubrey will conduct market surveys to provide information for plant expansion, product diversification and product development in Canada.

---

**Ed Styron,** a veteran of 20 years' sales and practical experience in instruments and control engineering and the oil industry, joins General Controls Co. as field representative in charge of sales.

With petroleum engineering training from Penn State, Styron worked in successive positions with Jensen Instrument Co., Fluor Corp., and Minneapolis-Honeywell. His experience includes previous connections with Atlantic Refining and Standard Oil.

---

Vitro Engineering Division of the Vitro Corporation of America names **Ralph L. Brown** as a director of industrial sales.

After graduation in chemical engineering from RPI in 1947, Brown served with the Navy and then in successive positions with the Merco Centrifugal Co., Sharples Corp. and the Kellex Corp., the latter being a predecessor company of Vitro.

---

Graver Water Conditioning Co. enlists **J. D. Crell** as sales engineer for the New York City sales district.

With Graver for three years, Crell is experienced in all phases of industrial, municipal and industrial waste treatment.

He is a 1952 graduate of the U. of Michigan and became a junior member of the Institute that same year.


**You gotta be first...**

**to be best!***

*25 years ago, Alloy Fabricators started to build Stainless Steel, Monel, Inconel, Nickel and Aluminum Process Equipment. With this experience, naturally, they're your *best bet today!*

**It's Still Our Only Business — And We Mind It Well!**

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**FOR CONTINUOUS**
**FOR ACCURATE**
**DUST SAMPLING**
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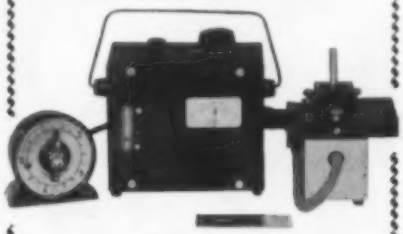

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Employs principle of thermal precipitation. Light weight—quiet—all electric Automatic timer—will also operate continuously—secures particulate matter suitable for microscopic, electron microscopic or visual and for permanent records on standard glass slides.

**Cost (complete) with carrying case $225.00**

*Send for descriptive literature*

Designer and manufacturer of continuous gravimetric and oscillating types of thermal precipitators

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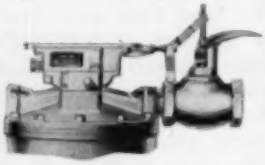
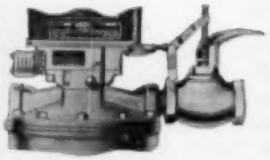
Widest selection of models for every plant...

Choose from the world's leading, most widely used line. XACTO meters are easily adapted with choice of dials and controls for changing needs to speed liquid handling operations and provide accurate accounting.

Recording printer mounts on meter. Prints quantity dispensed or received.



Delivers predetermined quantities up to 10,000 gallons, then shuts off.



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# Necrology

*Chemical Engineering Progress announces with regret the death of the following members of the profession.*

**Gustav Egloff,** director of research, Universal Oil Products Co., Des Plaines, Ill.

Considered one of the world's foremost petroleum scientists, Mr. Egloff had contributed some 650 articles relating to the petroleum industry and the chemistry of hydrocarbons. In addition he amassed almost 300 patents relating to petroleum processing.

During his career he predicted and saw developed the wide use of synthetics, including nylon, orlon and dacron—all created from petroleum by-products. In his many public appearances, Mr. Egloff emphasized the great possibilities for the future from petroleum product development.

He was educated at Cornell and Columbia U., having received his doctorate from the latter school. His membership in the A.I.Ch.E. dates back to 1922, five years after beginning his noteworthy career with Universal Oil.

---

**Carle M. Bigelow,** 65, consultant and former assistant to the general manager, fine chemicals division, American Cyanamid Co.

Author of numerous papers and articles on management, Mr. Bigelow had served with Cyanamid since 1934, his first position there being director of the pharmaceutical department.

He was recipient of two honorary degrees, one from Suffolk U. and the other from the U. of Rhode Island. Mr. Bigelow held degrees in chemical and mechanical engineering from the latter school.

---

A new international language, known as Interlingua, is being taught at New York University. The language, an auxiliary tongue with regular, simplified grammar and root words from many national languages, is designed to overcome language barriers faced by scientists and persons in foreign trade and travel. Ten scientific journals presently publish abstracts in the new tongue.

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Many readers of C.E.P. will be receiving invitations to supply personal data for the 4th edition of *Chemical Who's Who*, now being compiled. Lewis Historical Publishing Co., 265 W. 14th St., New York 11, N. Y. publishes the volume under the direction of W. S. Downs and Williams Haynes.

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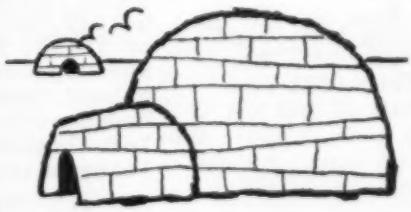

C-R CHILL-VACTOR units flash cool water, aqueous solutions and certain other liquids to temperatures down to 32° F. by partial evaporation at high vacuum.

As with all Croll-Reynolds equipment, the process is very simple. No chemical refrigerant is used. There are no moving parts. First cost as well as operating cost is usually less than for mechanical refrigeration.

CHILL-VACTOR units are producing chilled water in industrial plants throughout the world. Capacity varies from a few tons up to a few thousand tons.

The CHILL-VACTOR is only one type of steam-jet EVACTOR, manufactured by Croll-Reynolds. Others are producing high vacuum in many hundreds of plants. Let our technical staff help you with any or all of your vacuum problems.

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**CHILL-VACTOR Units • EVACTOR Steam Jets • Condensing Equipment**

# news and notes

COUNCIL VOTED THE DUES INCREASE mentioned here in the April column . . .

THE NEW DUES SCHEDULE represents an increase of one-sixth . . . For Members & Affiliates dues next year will be $21 . . . This also applies to Associate Members over thirty-five . . . For Associate Members under thirty-five dues will be $14, an increase of $2 . . . Student dues will remain at $1 . . .

THE REASON BEHIND THE INCREASE was discussed in April . . . In recent years more services have been rendered to members . . . We have started a new Journal, which for the present is creating a deficit . . . Not only have member services increased, but . . . owing to inflation . . . so has the cost of them . . .

COUNCIL WEIGHED SERIOUSLY the impact & meaning of a dues increase . . . There was no doubt that costs were such that the Institute had budgeted a deficit . . . The only other society with dues in the same bracket as the A.I.Ch.E. . . . the electrical engineers . . . too had found this year that they had to increase dues . . . Top dues in that society will now be $25, compared with our top of $21 . . . Their Junior dues are $20 . . .

COUNCIL CONDUCTED A NUMBER OF PERSONAL SURVEYS of members, of local sections, etc. . . . & reaction as reported at the Houston meeting was not unfavorable to the dues increase.

NEW ENGINEERING CENTER occupied a lengthy discussion period at Houston . . . C. G. Kirkbride, past president & our representative on the Committee of Five Presidents, discussed the recommendations of the committee . . .

THE COMMITTEE OF FIVE PRESIDENTS recommended Pittsburgh as the site for the Engineering Center . . . Council appointed a special committee composed of Holbrook, Kirkbride, Dodge, & Van Antwerpen to word a resolution . . . This is reported in toto on page 84 of this month's News Section . . . Kirkbride was requested to negotiate with Pittsburgh for the development of an over-all financial plan . . . The Housing Committee, under R. P. Kite, was asked to work on the financial considerations of the Institute . . . Council was insistent that we were not committing ourselves to Pittsburgh or any other site . . . what is needed are more facts & figures on how a move would affect our finances, budget, etc. . . .

ANOTHER COUNCIL STUDY has to do with registration fees at meetings . . . A special committee was appointed to investigate . . .

OTHER COUNCIL ACTIONS . . . Meetings at Salt Lake City, September 21-24, 1958 . . . Atlantic City, March 16-20, 1959 . . . San Francisco, December 6-10, 1959 . . . Approved were a Student Chapter for the University of Toledo . . . Local Section status for Toledo and New Haven sections . . . Student Chapter Counselors appointed . . . A. J. Chase to replace Richard E. Durst at the University of Maine . . . Aaron Rose to replace D. F. Chamberlain at Washington University . . . South Dakota School of Mines and Technology, R. F. Heckman . . . University of Tulsa, Paul Buthod . . . C. S. Boruff was appointed Institute representative to attend inauguration ceremonies for H.P. Rodes at Bradley University . . . G. O. Lof, Institute representative to the International Arid Lands meeting.

CENTRAL OHIO SECTION OF THE A.I.Ch.E. shows how interest of local students & colleges in professional activity can be stimulated . . . Each year the Central Ohio Section recognizes those students of Ohio State whose problems have been submitted in the Institute's national competition on the Student Problem . . . They award a one-year Student membership in the Institute & a one-year subscription to Chemical Engineering Progress . . . This year Bill Burt, past president of the Institute, made the award to Ohio State's Allan Evan Jones, at the Second Annual Conference for Engineers.

STUDENT MEETING AT THE SHAMROCK during the Houston meeting was outstanding . . . Presentations were so smooth & poised that the judging committee felt that the students were better than speakers at the regular sessions.

F.J.V.A.

Mr. Design Engineer

Mr. Purchasing Director

Mr. Plant Superintendent

## BROWN FINTUBE DESIGN PROTECTS YOU AGAINST

# YOUR *Occupational Hazard*

● If it hasn't happened to you yet,—it will. Beware!

Some day the company is going to decide to make a new product at your plant. The "market analysis and research" department will assure you the maximum requirement is so many thousand gallons a week. You'll design the plant . . . buy the equipment . . . get on stream . . . and then two or three months later — BOOM!

The market analysis boys "played it safe". Now — based on "newly available statistics" — they need 20% to 30% more output than the plant you just finished can possibly produce.

If you equipped that plant with "bundle" type exchangers you are going to have to wait, while you design — and fabricate — and install all new units. *And,* what are you going to do with the exchangers you just bought? Throw them away after only two or three months use?

*If* you had used Brown Fintube Heat Exchanger **Sections** in that plant you would need only to add a few sections or change the series-parallel manifolding. You would be running on the new duty,— or even an entirely different product — in just a few days — with a **minimum of new equipment** — and **nothing to throw away.**

That's what we call **"flexibility".** You can change from one duty to another any time you want. You can even dismantle an exchanger, ship the sections to one or three or four different plants, and put them right back in service again.

Many of the biggest, best known and lowest cost companies are keeping **flexible** by using Brown Fintube **Sections** throughout their plants. Why don't you play it safe too? Available with mild steel, stainless, alloy and non-ferrous fintubes — in standard sizes — for a wide range of capacities and pressures. Send for Bulletin No. 512. It gives full details. And plan on keeping your plant **flexible** with Brown Fintube **Sections.** They will really save you money!

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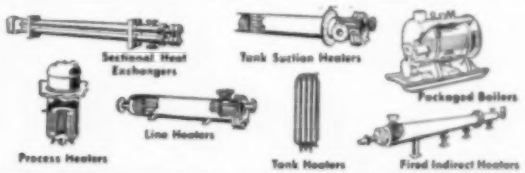


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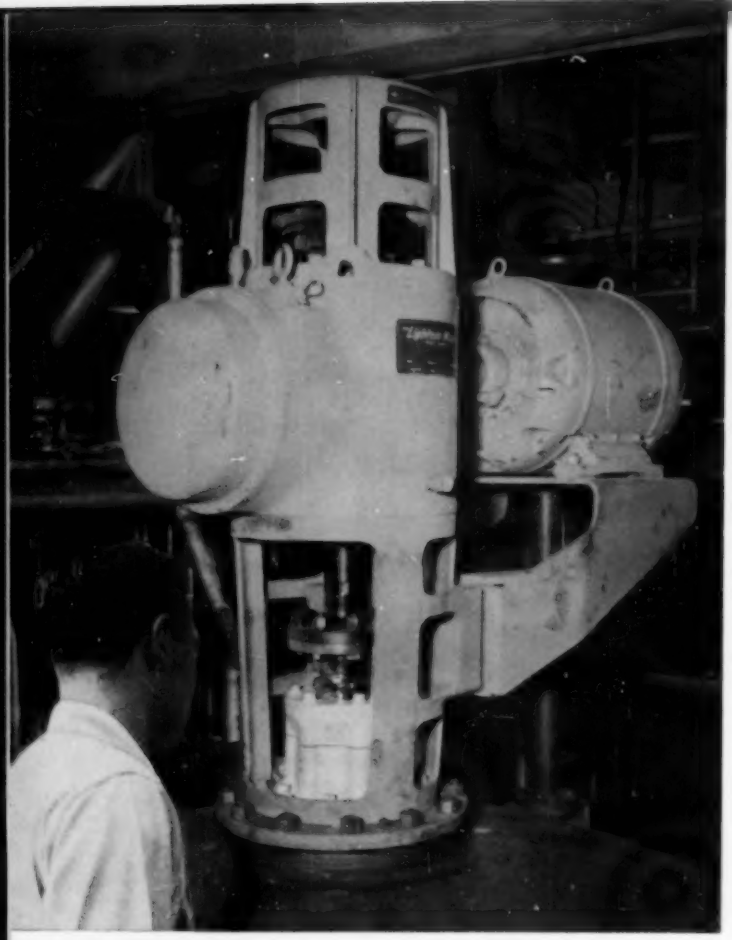
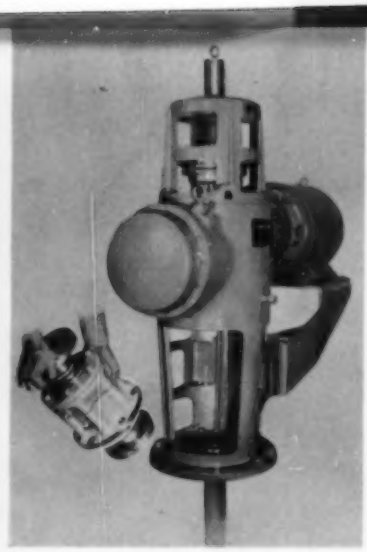
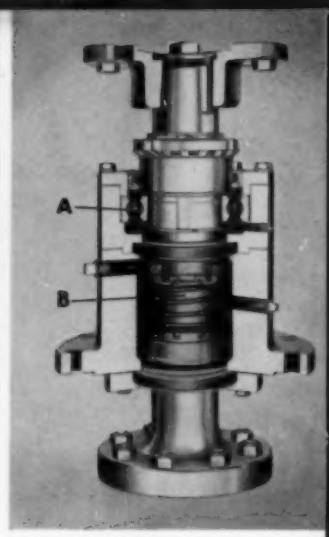




**IF YOU CAN USE A WRENCH,** you can replace a LIGHTNIN rotary seal in a few minutes. The mixer stays on the tank. Just unbolt and lift out this one-piece cartridge assembly; bolt a new one in its place; you're back in operation.




**SMOOTH RUNNING.** Prelubricated mixer shaft bearing (A) is part of seal assembly, close to seal for proper shaft support. But seal lubricant chamber (B) is separate from bearing—so you can choose best seal lubricant for your needs, without regard to bearing lubricant. Seal is stocked in wide range of designs and corrosion-resistant materials.

**NEW LOOK** in fluid mixing. This seal cartridge takes the place of a stuffing box; runs for years without adjustment; handles pressures to 1200 psig, temperatures from −120°F. to +485°F. Seals are optional equipment on LIGHTNIN top entering, side entering, and bottom entering mixers.

*Newest cost-saver for fluid mixing:*

## End stuffing box repacking . . . forever

### *with a rotary seal that's easy to replace*

You may get a whole new concept of the ease of mixing fluids under pressure or vacuum, when you read this story.

For here is a rotary seal that gives you leakproof, low-maintenance fluid mixing for *years,* under most conditions.

Yet *anyone can replace this seal in a few minutes,* if necessary. Without dismantling or demounting the mixer. Without draining the tank. And *without special skill.*

Here's what you gain when you specify LIGHTNIN Mixers with new LIGHTNIN Seals:

1. *You end leakage*—for good. The seal positively will not leak during its operating life. You can get standard LIGHTNIN Seal assemblies to handle pressures as high as 1200 psig; temperatures from −120°F. to +485°F. Special designs are available for more extreme conditions.

2. *You eliminate the cost* of repacking stuffing boxes. The LIGHTNIN Seal takes the place of a stuffing box. Under most conditions, it runs for *years* without changing.

3. *You stop costly "nursing"* of stuffing boxes. The seal *never* needs adjustment.

4. *You can replace* a LIGHTNIN Seal *in a few minutes,* should it ever become necessary. Only one *cartridge* component to unbolt and replace—and you're back in operation. Anyone who can handle a wrench can do it.

Already, many chemical processors are using LIGHTNIN Seals.

Users report maintenance savings running into many thousands of dollars yearly.

Your LIGHTNIN Mixer representative can give you the full story—show you how much *you* can save. Call him today. Or get the facts by mail: Send the coupon for 8-page, fully illustrated bulletin.

***Get the cost-cutting facts now...*** New 8-page Bulletin B-111 shows how you get maintenance-free sealing that really slashes fluid mixing cost to a new low. Send also for LIGHTNIN Mixer catalogs listed here. Free—no obligation. Just check data you want, tear out and mail to us today with your name and company address.

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